

DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

United States Earthquakes, 1969

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and

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Preface

Readers of this issue of *United States Earthquakes* will note that the cover bears the name of a new agency under the U. S. Department of Commerce. The National Oceanic and Atmospheric Administration (NOAA) replaced the Environmental Science Services Administration (ESSA) on October 3, 1970, pursuant to Reorganization Plan No. 4 proposed by President Richard M. Nixon. Under the provisions of the plan, the National Oceanic and Atmospheric Administration absorbed the functions and organizations of ESSA, together with various other organizations involved in oceanic and atmospheric activities. Within NOAA, the National Ocean Survey (NOS) was established by combining the functions of the ESSA Coast and Geodetic Survey and the U. S. Lake Survey (from the Department of the Army).

Since the work reported in *United States Earthquakes, 1969* was carried on before the formation of NOAA, the organizational citations in the text are those used at that time. However, addresses given for requesting seismological data are for the new NOAA organizations.

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Introduction

United States Earthquakes, the annual report of the National Earthquake Information Center, has been published each year since 1928. This report gives brief descriptions of earthquake effects in the United States, including summaries of all shocks that were noted by residents of the Panama Canal Zone, Puerto Rico, and the Virgin Islands. Principal earthquakes of the world for the calendar year also are listed.

Noninstrumental information used in this compilation includes data from the Weather Bureau, whose observers prepare periodic reports on local seismic activity; telegraphic information collected by Science Service, Washington, D.C.; bulletins of the Seismological Society of America; special reports of other organizations; newspaper clippings; and descriptive material submitted by interested individuals.

Instrumental data utilized in earthquake locations are obtained from seismological observatories (listed on page 4) and from cooperating seismograph stations worldwide. Instrumental epicenters are issued biweekly and monthly in the *Preliminary Determination of Epicenters* reports (see *Teleseismic Results*, page 3). Refined epicenter computations are published in the monthly *Seismological Bulletin*, usually 2 or more years after the seismic events.

The National Earthquake Information Center coordinates, insofar as possible, the collection of all types of earthquake information, with the special objective of correlating instrumentally determined earthquake locations with noninstrumental reports received from the region of the epi-

center and surrounding areas. This is achieved through intensive regional investigations by local organizations and the NEIC. This information is used to map the seismic areas of the country in order to promote public safety through a better understanding of earthquake phenomena. Since the success of the general information service depends largely on the cooperation of local officials and citizens, all who receive earthquake questionnaire cards are urged to complete and return them to the office indicated.

EARTHQUAKE INFORMATION SERVICES

In August 1966, the National Earthquake Information Center (NEIC) was established at the Coast and Geodetic Survey Headquarters at Rockville, Md. This Center is a focal point for the dissemination of seismic information, both immediate and historical, for both technical and general users.

The first new service from the Center was an expanded earthquake reporting system to provide accurate hypocenter locations and magnitude values as quickly as possible to the press and other interested groups. These results are available within 2 to 3 hours for earthquakes of magnitude $6\frac{1}{2}$ or larger; seismic events smaller in magnitude are dealt with upon request or on receipt of a press report.

The global facilities of the Coast and Geodetic Survey and its seismograph stations, and the facilities of cooperating observatories, are used to provide data for the earthquake reporting system. When a large

earthquake occurs, participating observatories telephone or telegraph observations to the National Meteorological Center at Suitland, Md. This information is relayed to a duty seismologist at the NEIC who locates the epicenter graphically on a large world globe and scales the magnitude. This information, together with background and explanatory comments for nonseismologists, is released via Weather Bureau circuits and directly to news media.

The Center serves as a focal point for many additional seismological services. These include preparing seismic histories for engineers, actuaries, and other scientists, and answering direct inquiries from various groups and individuals.

The NEIC also publishes a bimonthly *Earthquake Information Bulletin* which contains information on past and continuing studies in this field and describes techniques used in the investigations of earthquakes and related phenomena. The *Bulletin* is published to provide earth science information the layman can understand and use. Although back issues of this magazine are not available, the January-February 1971 *Bulletin* and subsequent issues may be ordered from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402; annual subscription \$1.50 (50 cents additional for foreign mailing); price per copy, 30 cents.

The Coast and Geodetic Survey maintains the Seismological Field Survey in San Francisco, Calif., where earthquake information is collected by field investigation and questionnaire canvass for the Pacific Coast and Western Mountain States. Details on general effects and damage are contained in the quarterly *Abstracts of Earthquake Reports for the United States*. Active cooperation in this work is provided by the University of California Seismographic Station at Berkeley, the Seismological Laboratory at Pasadena, and by collaborators in seismology. The following

served as collaborators to the Coast and Geodetic Survey during 1969:

Arizona.—Dr. Richard T. Moore, Arizona Bureau of Mines, University of Arizona, Tucson.

Colorado.—Prof. Warren L. Longley, University of Colorado, Boulder.

Idaho.—Dr. Melvin W. Jackson, Argonne National Laboratory, Idaho Falls.

Montana.—Prof. Stephen W. Nile, 320 Ranch, Gallatin Gateway.

Nevada.—Dr. David B. Slemmons, University of Nevada, Reno.

New Mexico.—Prof. Stuart A. Northrop, University of New Mexico, Albuquerque.

Utah.—Prof. J. Stewart Williams, Utah State University, Logan.

Oregon.—Dr. Peter Dehlinger, Oregon State University, Corvallis.

Washington.—Prof. Howard A. Coombs, University of Washington, Seattle.

Commercial agencies on the West Coast that render valuable services include telephone, power, oil, railroad, and insurance companies. Companies interested in the manufacture of earthquake-resistive building materials are also active, as are various organizations of structural engineers and architects.

Earthquake information was collected in other parts of the country during 1969 by the following:

Northeastern Region.—Rev. Daniel J. Linehan, S.J., Weston College, Weston, Mass.

Eastern Region.—Dr. Gerald R. MacCarthy, University of North Carolina, Chapel Hill (for earthquakes in North Carolina).

Central Region.—Rev. Dr. Victor J. Blum, S.J., St. Louis University (for earthquakes in the central Mississippi Valley area); Dr. E. J. Walter, John Carroll University, Cleveland, Ohio (for earthquakes in Ohio); and Mr. Berlen C. Moneymaker, Tennessee Valley Authority, Knoxville (for earthquakes in Tennessee).

EPICENTER MAPS

Figure 1 is designed to show the existence of damaging earthquakes in the United States through 1969. Some of the most prominent historical earthquakes displayed in figure 1 are listed on page 6.

Figure 2 shows earthquake distribution in the United States during 1969. In a few instances where instrumental control is not satisfactory or where results of investigations are inadequate, the plotted epicenters show the existence, rather than the precise locations, of the earthquakes. Earthquakes in the California area are plotted when felt reports are received from several towns. Feeble earthquakes, and minor aftershocks of large earthquakes, usually are not shown on this map. A numeral associated with a dot indicates the number of shocks which occurred at that location. Bulletins of the University of California Seismographic Station and the Seismological Laboratory should be consulted for further details on epicenters, and for data on other California shocks.

The selection of isoseismal or "felt area" maps (figs. 3-9) is governed largely by the size of the area affected; the minimum radius generally is about 50 miles. This means that sharp, localized shocks of intensity VI (mostly in California) may not be shown on such maps, whereas others of intensity IV and V (largely in the Eastern and Central States) will often be shown. Felt and nonfelt reports from towns are designated on isoseismal maps by open and solid circles, respectively. Intensities higher, or lower, than those in the specific isoseismal zones are noted frequently and are indicated by small numerals beside the open circles.

TELESEISMIC RESULTS

The seismological observatories used in the epicenter program of the National Earthquake Information Center are listed on page 4. During the year the locations of 5,311 epicenters were announced in the biweekly *Preliminary Determination of Epicenters* (PDE) list. To provide rapid service, these epicenters are released as soon as sufficient information has accumulated to ensure a reasonable degree of accuracy. The results are preliminary and do not always agree with later epicenters determined from additional seismic readings or from new data with critical azimuths and distances. For special studies, an inquiry should be made to the NEIC office for possible recomputations of epicenters of interest. The biweekly PDE listing is available without charge to collaborators in seismology. The *Preliminary Determination of Epicenters Monthly Listing* is now available from the Superintendent of Documents, Government Printing Office, Washington, D. C. 20402; annual subscription price, \$1.50 (50 cents additional for foreign mailing); price per copy, 15 cents.

The NEIC publishes the results of its teleseismic and cooperating stations in the monthly *Seismological Bulletin* and quarterly *Antarctic Seismological Bulletin*. All seismogram interpretations are tabulated together with epicenters based on the published data and instrumental results from seismic stations worldwide.

For detailed instrumental data regarding the stations which follow, including instrumentation, constants, and other information, refer to *Seismological Bulletin*, MSI-349, and *Antarctic Seismological Bulletin*, MSI-349A, January 1970. Collaborators who wish to receive these reports upon issuance should request the NEIC to place their names on the CGS-7 mailing list.

Coast and Geodetic Survey and Cooperating Seismograph Stations
[C&GS stations are listed in first column.]

Adak, Alaska	Balboa Heights, C.Z.
Albuquerque, N. Mex.	(The Panama Canal Co.)
Baker, Oreg. (Array)	Boulder City, Nev.
Barrow, Alaska	(Bureau of Reclamation)
Biorka, Alaska	Bozeman, Mont.
Byrd, Antarctica	(Montana School of Mines)
College, Alaska (2)	Butte, Mont.
Gilmore Creek, Alaska	(Montana School of Mines)
Guam, Mariana Islands	Columbia, S.C.
Honolulu, Hawaii (5)	(Univ. of South Carolina)
Kipapa, Hawaii	Eureka, Nev.
Kodiak, Alaska	(Eureka Corp., Ltd.)
Las Vegas, Nev.	Flaming Gorge, Utah
McMinnville, Tenn. (Array)	(Bureau of Reclamation)
Middleton Island, Alaska	Glen Canyon, Ariz.
Newport, Wash.	(Bureau of Reclamation)
Nordman, Idaho	Hungry Horse, Mont.
Palmer, Alaska (3)	(Bureau of Reclamation)
San Juan, P.R.	Philadelphia, Pa.
Sitka, Alaska	(The Franklin Institute)
South Pole, Antarctica	Salt Lake City, Utah
Tucson, Ariz. (2)	(Univ. of Utah)
Ukiah, Calif.	San Luis Dam, Calif.
Washington, D.C.	(California State Department
Washington Science Center,	of Water Resources)
Rockville, Md.	

STRONG-MOTION SEISMOGRAPH NETWORK

The maintenance of a network of strong-motion seismographs and the analysis of the records of destructive earthquake motions thus obtained are functions of the Coast and Geodetic Survey in connection with a broad, cooperative research program being conducted on the Pacific Coast with several local organizations and institutions interested in the engineering aspects of the earthquake problem. More details concerning this subject may be found in the section Strong-Motion Seismograph Results, page 61. Locations of the strong-motion stations operated by the C&GS Seismological Field Survey are shown in figure 10. These now include eight stations in Central and South America, one each in Connecticut and Missouri, and three in South Carolina.

The preliminary analyses of strong-motion records are published in the *Quarterly*

Engineering Seismology Bulletin. Revised analyses are presented in tables 4 and 5.

MAGNITUDE AND INTENSITY RATINGS

Magnitude, stated according to the Richter scale, is a measure of the energy release at the focus of an earthquake as determined by the amplitudes produced on a seismogram. Although the magnitude scale has no "top" nor "bottom" values, the highest ever recorded was magnitude 8.9 and the lowest about -3. On this logarithmic scale, a magnitude 8 earthquake represents recorded amplitudes ten times larger than those for a magnitude 7 earthquake, 100 times larger than a shock of magnitude 6, etc. (see *Bulletin of the Seismological Society of America*, Vol. 32, No. 3, 1942).

Intensity rating, expressed on the Modi-

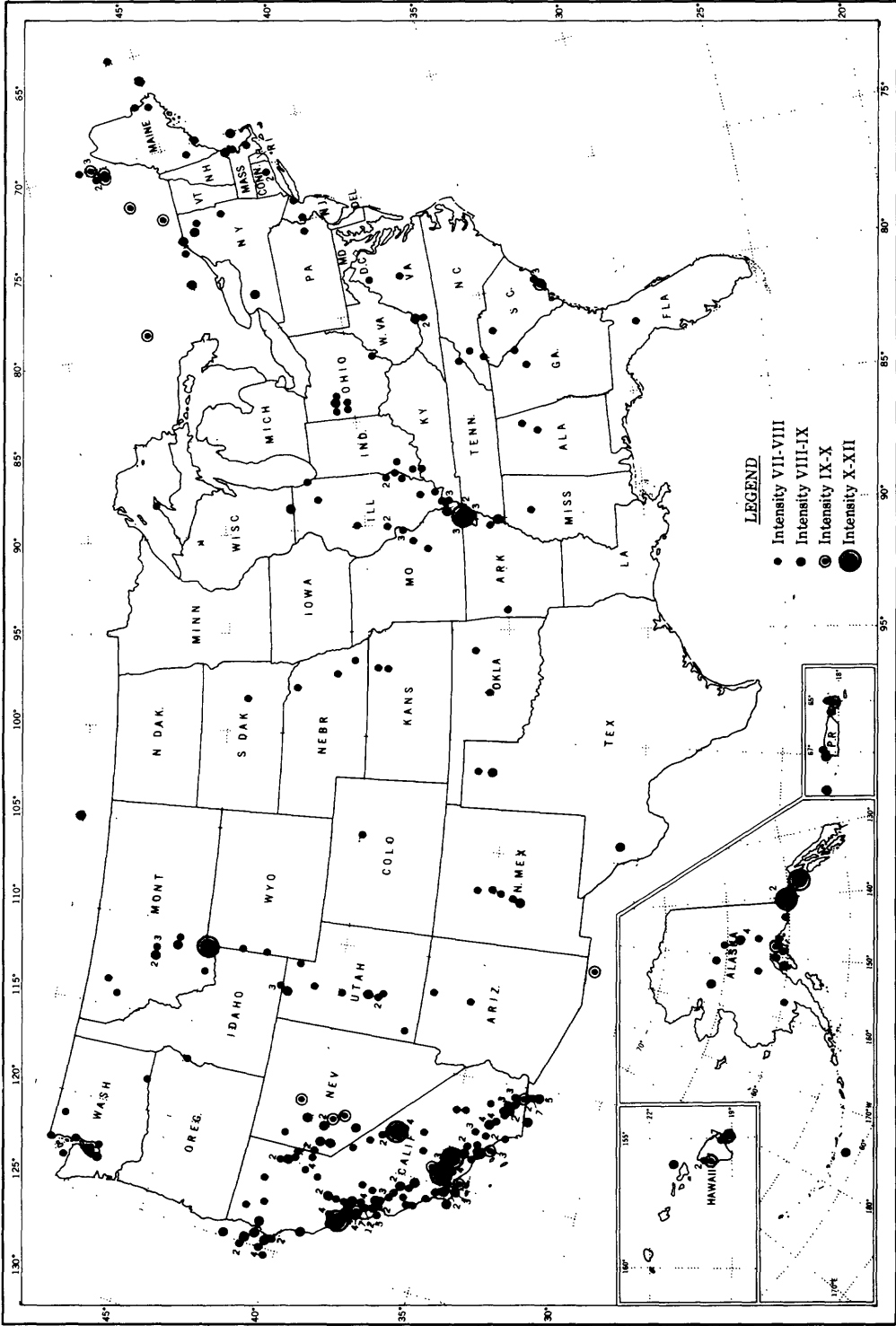


FIGURE 1.—Damaging earthquakes in the United States through 1969.

List of Prominent Earthquakes of the United States (see fig. 1)

Date	Locality	N. Lat.	W. Long.	Area	Modified Mercalli Intensity
		deg	deg	sq. mi.	
1663 Feb. 5	St. Lawrence River region -----	47.6	70.1	750,000	X
1755 Nov. 18	East of Cape Ann, Mass -----	42.5	70.0	300,000	VIII
1811 Dec. 16	Near New Madrid, Mo -----	36.6	89.6	2,000,000	XII
1812 Jan. 23					
1812 Feb. 7	Off coast of southern California -----	34	120	-----	X
1812 Dec. 21					
1836 June 10	San Francisco Bay -----	38	122	-----	IX-X
1838 June	San Francisco region -----	37½	122½	-----	X
1852 Nov. 9	Near Fort Yuma, Ariz -----	33	114½	-----	VIII-IX
1857 Jan. 9	Near Fort Tejon, Calif -----	35	119	-----	X-XI
1865 Oct. 1	Fort Humboldt and Eureka, Calif ---	41	124½	-----	VIII-IX
1865 Oct. 8	Santa Cruz Mts., Calif -----	37	122	-----	VIII-IX
1868 Apr. 2	Near south coast of Hawaii -----	19	155½	-----	X
1868 Oct. 21	Hayward, Calif -----	37½	122	-----	IX-X
1872 Mar. 26	Owens Valley, Calif -----	36½	118	125,000	X-XI
1886 Aug. 31	Northwest of Charleston, S.C -----	32.9	80.0	2,000,000	IX-X
1892 Feb. 23	Northern Baja California -----	31½	116½	-----	VIII-IX (U.S.)
1892 Apr. 19	Vacaville, Calif -----	38½	122½	-----	IX
1892 Apr. 21	Winters, Calif -----	38½	122	-----	IX
1893 Apr. 4	Northwest of Los Angeles -----	34½	118½	-----	VIII-IX
1895 Oct. 31	Charleston, Mo -----	37.0	89.4	1,000,000	VIII
1898 Apr. 14	Mendocino County, Calif -----	39	124	-----	VIII-IX
1899 Sept. 3	Yakutat Bay, Alaska -----	60	142	-----	XI
1899 Sept. 10	----- do -----	60	140	-----	XI
1899 Dec. 25	San Jacinto and Hemet, Calif -----	33½	116½	100,000	IX
1906 Apr. 18	Northwest of San Francisco, Calif ---	38	123	375,000	XI
1915 Oct. 2	Pleasant Valley, Nev -----	40½	117½	500,000	X
1918 Apr. 21	Riverside County, Calif -----	33¾	117	150,000	IX
1921 Sept. 29	Elsinore, Utah -----	38.8	112.2	-----	VIII
1921 Oct. 1					
1922 Mar. 10	Cholame Valley, Calif -----	35¾	120¼	100,000	IX
1925 Feb. 28	St. Lawrence River region -----	47.6	70.1	2,000,000	VIII
1925 June 27	Helena, Mont -----	46.0	111.2	310,000	VIII
1925 June 29	Santa Barbara, Calif -----	34.3	119.8	-----	VIII-IX
1927 Nov. 4	West of Point Arguello -----	34½	121½	-----	IX-X
1931 Aug. 16	Western Texas -----	30.6	104.1	450,000	VIII
1932 Dec. 20	Western Nevada -----	38.7	117.8	500,000	X
1933 Mar. 10	Long Beach, Calif -----	33.6	118.0	100,000	IX
1934 Jan. 30	Southeast of Hawthorne, Nev -----	38.3	118.4	110,000	VIII-IX
1934 Mar. 12	Near Kosmo, Utah -----	41.7	112.8	170,000	VIII
1935 Oct. 18	Northeast of Helena, Mont -----	46.6	112.0	230,000	VIII
1935 Oct. 31	----- do -----	46.6	112.0	140,000	VIII
1940 May 18	Southeast of El Centro, Calif -----	32.7	115.5	60,000	X
1949 Apr. 13	Western Washington -----	47.1	122.7	150,000	VIII
1952 July 21	Kern County, Calif -----	35.0	119.0	160,000	XI
1954 July 6	East of Fallon, Nev -----	39.4	118.5	130,000	IX
1954 Aug. 23	----- do -----	39.6	118.5	150,000	IX
1954 Dec. 16	Dixie Valley, Nev -----	39.3	118.2	200,000	X
1958 July 9	Southeastern Alaska -----	58.6	137.1	100,000	XI
1959 Aug. 17	Near Hebgen Lake, Mont -----	44.8	111.1	600,000	X
1964 Mar. 27	Southern Alaska -----	61.0	147.8	700,000	IX-X
1965 Apr. 29	Northwestern Washington -----	47.4	122.3	130,000	VIII

fied Mercalli Intensity Scale of 1931 (see next section) is a measure of the effects of an earthquake on people and objects, as determined by experienced observers. It is a result of many factors, including magnitude of the earthquake, distance from its epicenter, local geological conditions, and structural properties of buildings. An earthquake in a populated area will have several *intensities*, depending on the local factors mentioned, but only one *magnitude* (which may vary slightly at different observatories due to variations in equipment and methods of estimating).

MODIFIED MERCALLI INTENSITY SCALE OF 1931

The National Earthquake Information Center reports all intensities on the Modified Mercalli Intensity Scale of 1931¹. The abridged version of this scale, with equivalent intensities in the Rossi-Forel Scale (see reference), is given below.

- I. Not felt except by a very few under specially favorable circumstances. (I Rossi-Forel Scale)
- II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale)
- III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale)
- IV. During the day, felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale)
- V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale)
- VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale)
- VII. Everybody runs outdoors. Damage *negligible* in buildings of good design and construction; *slight* to *moderate* in well-built ordinary structures; *considerable* in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale)
- VIII. Damage *slight* in specially designed structures; *considerable* in ordinary, substantial buildings, with partial collapse; *great* in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX Rossi-Forel Scale)
- IX. Damage *considerable* in specially designed structures; well-designed frame structures thrown out of plumb; *great* in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel Scale)

¹ Harry O. Wood and Frank Neumann, in *Bulletin of the Seismological Society of America*, Vol. 21, No. 4, December 1931.

- X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale)
- XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
- XII. Damage *total*. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

EARTHQUAKE HISTORY

A history of the more important earthquakes of the country appears in Publication No. 41-1, *Earthquake History of the United States*. Part I, revised 1963 edition, includes stronger earthquakes of the United States, exclusive of California and

western Nevada; Part II, revised 1963 edition, covers the stronger earthquakes of California and western Nevada. These reports are being revised and will be issued under one cover early in 1972.

A history of minor activity is covered largely in a series of references listed in Publication No. 41-1, noted above, in recent reports of the Coast and Geodetic Survey, and in the *Bulletin of the Seismological Society of America*, Vol. 29, No. 1, January 1939. The last reference gives detailed information for California and other Pacific Coast earthquakes, and contains all information appearing in early catalogs published by the Smithsonian Institution.

C&GS Special Publication 282, *Earthquake Investigation in the United States*, revised 1969 edition, explains the more important facts about earthquakes and outlines the role played by the Federal Government and private seismological organizations in dealing with the earthquake problem. It discusses briefly all major earthquakes through 1968 in the United States, Puerto Rico, and Panama Canal Zone, and shows in tabular form, dollar damage and lives lost as a result of strong U.S. shocks.

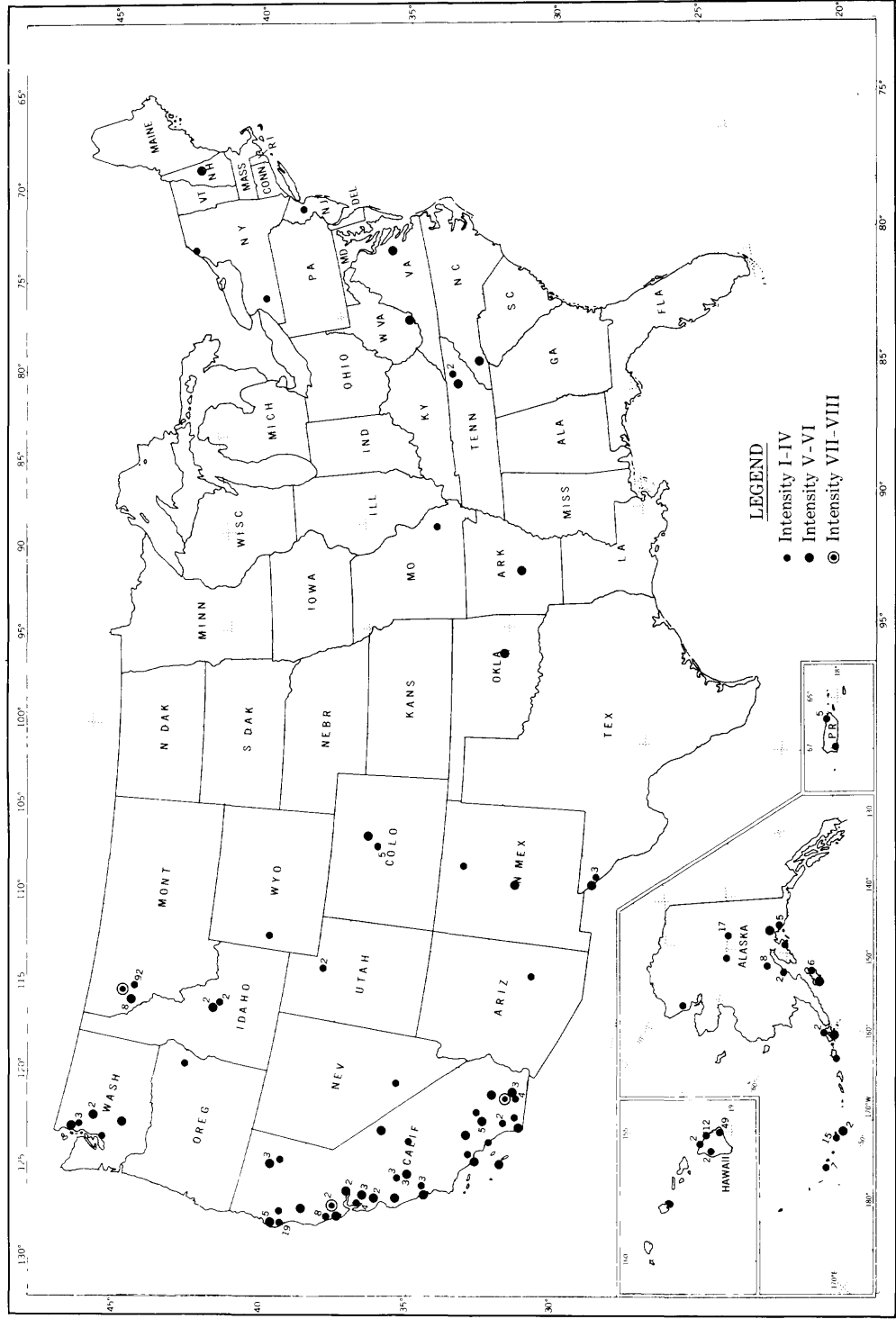


FIGURE 2.—United States earthquake epicenters for 1969.

Summary of Earthquake Reports

The following symbols are used to indicate authority for times or epicenters in the regions which follow: P, reported by the Seismological Laboratory, California Institute of Technology, Pasadena; B, reported by the Seismographic Station, University of California, Berkeley; NESAs, reported by the Northeastern Seismological Association, Weston, Mass.; JSAs, reported by the Jesuit Seismological Association, St. Louis, Mo.; and W, reported by the National Earthquake Information Center (NEIC) at Rockville.

Two magnitudes may now be determined by the NEIC: Surface wave magnitude (M_s) and body wave magnitude (M_b). Each represents an average of individual station magnitudes which are determined from reported periods and amplitudes of representative waves. Body wave magnitude is computed from *P* (primary) phases only, in the manner defined by Gutenberg and Richter¹. Surface wave magnitude is determined using a formula recommended by the International Committee on Magnitudes. Magnitudes reported by other organizations are identified by the symbols given in the preceding paragraph.

An asterisk (*) indicates instrumental origin time of the earthquake when coordinates of the epicenter are given. Otherwise, instrumental times shown with asterisks indicate the arrival time at a nearby station.

When more than one degree of intensity is reported from a town, the town is listed under the highest reported. More details

will be found in the quarterly *Abstracts of Earthquake Reports for the United States*, MSA series, issued on mailing list CGS-3.

EARTHQUAKE ACTIVITY IN THE VARIOUS STATES

This section summarizes the earthquake data in the regions which follow. Intensities of earthquakes for which no intensity ratings are given range from I to IV.

Alaska: (Intensity V and above). Feb. 5, V; May 14, V.

Arizona: Apr. 14; felt southern California earthquake of Apr. 28; Dec. 25.

Arkansas: Jan. 1, VI.

California: (Intensity VI and above). Feb. 7, VI; 27, VI; Apr. 28, VII; June 7, VI; Oct. 1, VII–VIII; 27, VI.

Colorado: Apr. 17, IV; May 23, V; 25, IV; Sept. 13.

Georgia: Felt Tennessee earthquake of July 13; felt West Virginia earthquake of Nov. 19, V.

Hawaii: Several were felt. None had intensity designations (see page 45).

Idaho: Felt Montana earthquake of Apr. 1; Apr. 22, IV; 26, VI; May 3; 5, V.

Kentucky: Felt Tennessee earthquake of July 13, IV; felt West Virginia earthquake of Nov. 19, V.

Maryland: Felt West Virginia earthquake of Nov. 19, III.

Missouri: Felt Arkansas earthquake of Jan. 1, IV; Jan. 20.

Montana: Apr. 1, VII (Many slight aftershocks felt through September 28 are not listed here); Apr. 28, V; 30, V; May

¹Gutenberg, B. and C. F. Richter, "Magnitude and Energy of Earthquakes," *Annali di Geofisica*, Vol. 9, pp. 1–15, 1956.

6, V; June 21, V; Sept. 14, VI; Oct. 3; 7, V; 13, V; 14; 28; 30; Nov. 4 (3); 6, VI; 6; 7; 12; 24; Dec. 12, IV; 12; 25, IV; 25; 26; 29.

Nevada: Jan. 5; felt southern California earthquake of Apr. 28; felt California-Nevada border earthquake of Oct. 3.

New Hampshire: Aug. 6, V.

New Jersey: Apr. 24.

New Mexico: Jan. 29, V; July 4, IV.

New York: Aug. 12, IV; Oct. 9, IV.

North Carolina: Felt Tennessee earthquake of July 13, IV; felt West Virginia earthquake of Nov. 19, V; Dec. 13, V.

Ohio: Felt West Virginia earthquake of Nov. 19, IV.

Oklahoma: May 2, V.

Oregon: Felt Idaho earthquake of Apr. 26; Aug. 14.

South Carolina: Felt West Virginia earthquake of Nov. 19, V.

Tennessee: Felt Arkansas earthquake of Jan. 1, IV; July 13, V; 14; 15; felt West Virginia earthquake of Nov. 19, V.

Texas: May 12, VI; 12 (3).

Utah: Jan. 23; Feb. 16, IV.

Virginia: Felt Tennessee earthquake of July 13, IV; felt West Virginia earthquake of Nov. 19, VI; Dec. 11, V.

Washington: Felt British Columbia earthquake of Feb. 14, V; Mar. 5, IV; Aug. 13 (2); 19; Oct. 9, V; Nov. 1, V; 9, V; 28, IV.

West Virginia: Nov. 19, VI.

Wyoming: Aug. 27.

EARTHQUAKE ACTIVITY OUTSIDE THE UNITED STATES

Panama Canal Zone: Aug. 17.

Puerto Rico: Jan. 28; 29; Mar. 20; felt Virgin Islands earthquake of Aug. 1; Sept. 28, IV; felt Leeward Is. shock of Dec. 25.

Virgin Islands: Aug. 1.

NORTHEASTERN REGION

[75th Meridian or Eastern Standard Time]

August 6: 11:02:54.9*. Epicenter in the Moultonboro-Ossippe, N. H., area, NESA. V. Felt by several in Moultonboro. Window cracked, small objects fell, and windows and dishes rattled. Glasses were knocked off shelf; one broke.

August 12: 21:42. Felt over a small area in northwestern New York. Intensity IV at Attica; intensity I-III at Varysburg and Warsaw.

October 9: 19:07:06.8*. Epicenter 46.2° north, 75.1° west, southern Quebec, Canada, W. Magnitude 3.9. Intensity IV at Massena, N. Y.

EASTERN REGION

[75th Meridian or Eastern Standard Time]

April 24: 19:14:41.4*. Epicenter 40.7° north, 74.3° west, New Jersey, W. Felt at Hopewell and Princeton.

July 13: 16:51:09.4*. Epicenter 36.1° north, 83.7° west, eastern Tennessee, W. Magnitude 3.5. V. Felt over approximately 20,000 square miles of Tennessee, North Carolina, Virginia, Kentucky, and Georgia (see fig. 3). At Jefferson City, some rocks fell in several zinc mines, and a few chimney bricks were shaken loose. Plaster and concrete reportedly cracked at Knoxville; plaster cracked at Seymour.

INTENSITY V IN TENNESSEE:

Clinton.—Windows, doors, and dishes rattled loudly; building creaked strongly. Trees and bushes shook.

Jefferson City.—Felt by nearly everyone; frightened few. Houses shook strongly. "Several zinc mines in area reported some loose rock fell. There were reports that a few bricks in chimneys were shaken loose."

Knoxville.—Felt by nearly everyone. Abrupt onset, followed by a very strong trembling motion. Houses shook strongly; furniture jumped up and down. Picture

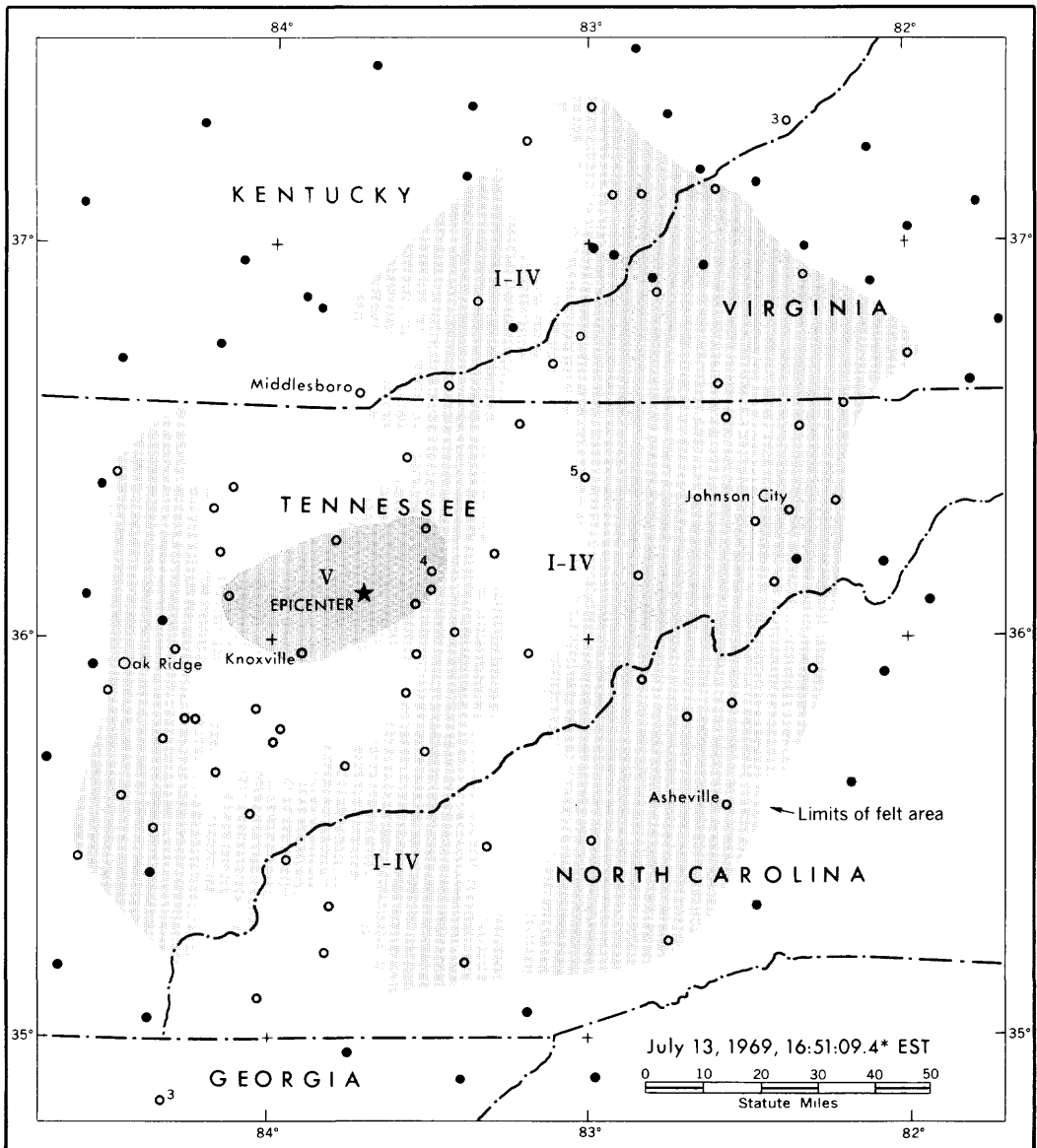


FIGURE 3.—Area affected by eastern Tennessee earthquake of July 13.

fell from wall. A few claims of cracked plaster and concrete.

Maynardville.—Felt by nearly everyone. Doors and windows rattled. Rumbling noise heard.

New Market.—Felt by most. Strong ground motion noted. Golfers reported that ground motion caused a golf ball to roll.

Rogersville.—Felt by all. Thunderous earth noises.

Rutledge.—Felt by all. Small objects shifted. Earth noises heard.

INTENSITY IV IN TENNESSEE:

Athens, Blountville, Bristol, Dandridge, Elizabethton, Fort Loudon Dam, Greenback, Hartford, Huntsville, Jacksboro,

Johnson City, Kingsport, La Follette, Lake City, Lenoir City, Loudon, Madisonville, Maryville, Morristown, Potter Ford, Sevierville, Sneedville, Tallassee, and Tazewell.

INTENSITY IV IN NORTH CAROLINA:

Andrews, Asheville, Brevard (near), Burnsville, Murphy, and Tapoco.

INTENSITY IV IN VIRGINIA:

Big Stone Gap, Ewing, Jonesville, Pennington Gap, Pound, and St. Paul.

INTENSITY IV IN KENTUCKY:

Hazard, Hindman, Loyall, and Whitesburg.

INTENSITY I-III IN TENNESSEE:

Alcoa, Cherokee Dam, Douglas Dam, Erwin, Gatlinburg, Grassy Cove, Greeneville, Jonesboro, Kingston, Louisville, Oak Ridge, Sweetwater, and Townsend.

INTENSITY I-III IN NORTH CAROLINA:

Cherokee, Franklin, Hot Springs, Mar-

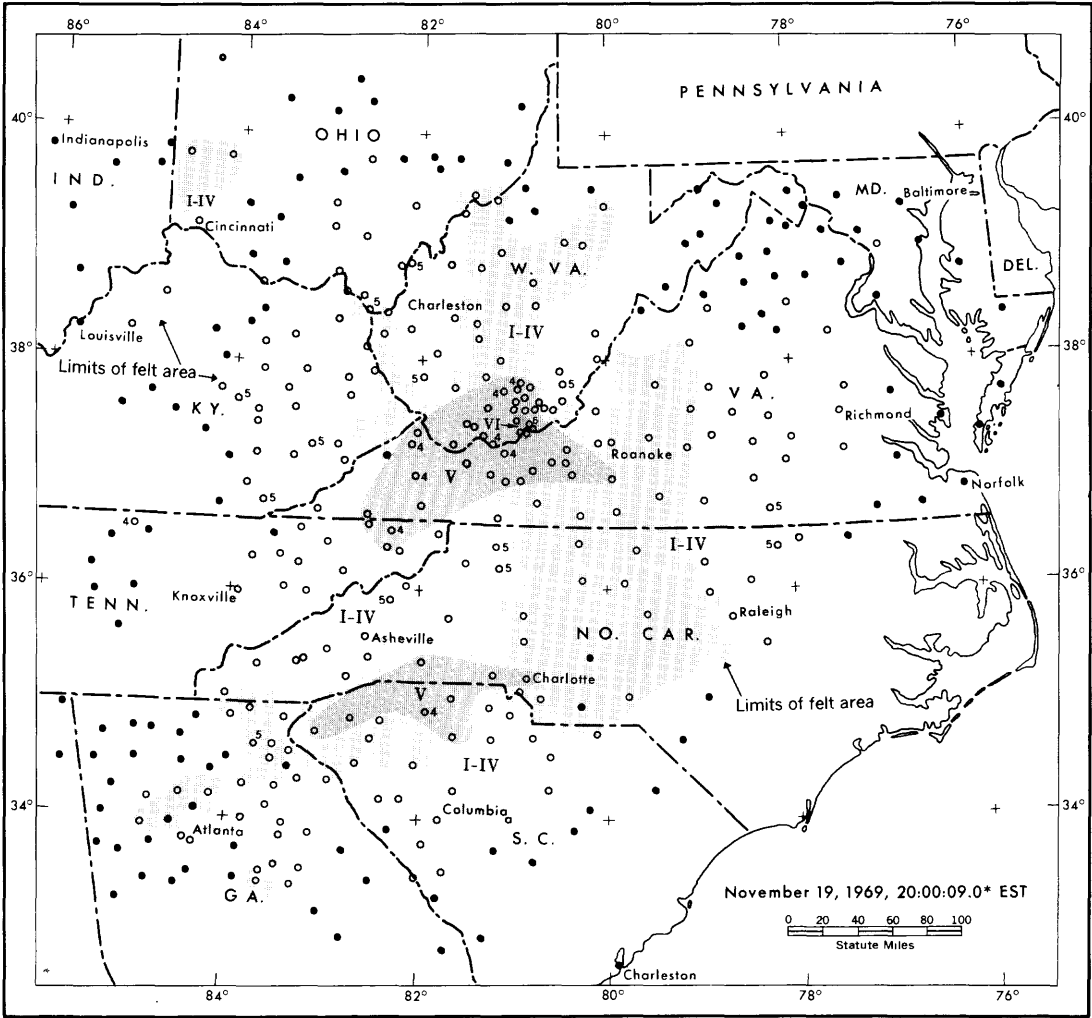


FIGURE 4.—Area affected by West Virginia earthquake of November 19.

shall, Mars Hill, Robbinsville and 11 miles east of, and Waynesville.

INTENSITY I-III IN KENTUCKY:

Blackey, Elkhorn City, Gamaliel, and Middlesboro.

INTENSITY I-III IN VIRGINIA:

Abingdon and Gate City.

INTENSITY I-III IN GEORGIA:

Blue Ridge.

July 14: 06:15. Knoxville, Tenn. The press reported this shock was much smaller than that of July 13 and that it was not noticed by many people.

July 24: 13:10. Knoxville, Tenn. III. People in tall buildings reported feeling this shock.

November 19: 20:00:09.0*. Epicenter 37.4° north, 81.0° west, West Virginia, W. Magnitude 4.3. VI. Felt over approximately 100,000 square miles of West Virginia, Virginia, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Ohio, and Maryland (see fig. 4). Only minor damage was sustained. It consisted chiefly of cracked and fallen plaster and broken windows at Athens, Leron, and Elgood, W. Va., and Glen Lyn and Rich Creek, Va. A paper by Bollinger and Hopper¹, Virginia Polytechnic Institute, states: "Field Surveys were conducted by the authors and Professor C. E. Sears on November 20-21, 1969. In addition to touring the epicentral region, the Virginia towns of Narrows, Rich Creek, and Glen Lyn, and the West Virginia towns of Kellysville, Elgood, Peterstown, and Princeton were visited. Earthquake damage observed during this survey . . . was of very limited occurrence and confined to old and structurally weak buildings."

INTENSITY VI IN WEST VIRGINIA:

Athens.—Felt by all and frightened many. Plaster and windows cracked. Damage slight. Small objects shifted. Loud earth noises.

Camp Creek.—Felt by all. Part of flue fell. "Up-and-down motion. Dish on table danced." Loud rumble.

Elgood.—Felt by and frightened all. General alarm. Several windows broken. Plaster cracked. Objects knocked off shelves (VPI survey).

Leron.—Felt by all; most extremely upset. Plaster and windows cracked. Telephones out of order. "Several windows broke in the Pipestem State Park." Loud earth noises.

INTENSITY VI IN VIRGINIA:

Collinsville.—Press reported a cornice was shaken from building.

Glen Lyn.—Felt by all and frightened many. Few instances of rocks rolling from mountains. Press reported plaster was knocked off nearly every wall in one house. Many windows, including display windows, were broken. Walls cracked in old concrete block house. Several reports of cracked and fallen plaster, objects knocked off shelves, and pictures knocked down. Report of few bricks knocked off a chimney and of a large boulder rolling onto railroad tracks (VPI survey).

Rich Creek.—Felt by and frightened all. Hanging objects swung violently. One plate glass store window broke; several reports of broken and fallen plaster and items knocked off shelves (VPI survey). Loud earth noises.

INTENSITY V IN WEST VIRGINIA:

Ballard, Ballengee, Coopers, Dawson, Dunns, Elkins, Flat Top, Forest Hill, Gilliam, Hinton, Itmann (windows cracked), Jumping Branch, Lewisburg, Logan (very light plaster cracks), Meadow Creek, Pineville, Pipestem (plaster cracks), Point Pleasant, Ramp (damage slight), Williamson, and Wyco.

INTENSITY V IN VIRGINIA:

Abingdon, Blacksburg, Boydton (6 miles west of), Christiansburg, Foster Falls, Gate City, Indian Valley, Pulaski, Radford, (several reports of plaster damage in vicinity), Rocky Mount, Rural Retreat (3

¹ Bollinger, G. A. and Margaret G. Hopper, "The Elgood, West Virginia, Earthquake of November 20, 1969 [G.m.t.]," *Earthquake Notes*, Vol. 41, March 1970.

miles northeast of), Tazewell (window already cracked now completely broken), Wise, and Wytheville.

INTENSITY V IN GEORGIA:

Cleveland.

INTENSITY V IN KENTUCKY:

Catlettsburg, Hazard, Irvine, and Pineville.

INTENSITY V IN NORTH CAROLINA:

Burnsville, Charlotte, Gastonia (plaster cracked), Laurel Springs, Rutherfordton (10 miles west of), Warrenton, and Wilkesboro.

INTENSITY V IN SOUTH CAROLINA:

Gaffney, Pickens (window and plaster cracked), Union, and Walhalla.

INTENSITY V IN TENNESSEE:

Johnson City and Kingsport (few new cracks in plaster).

INTENSITY IV IN WEST VIRGINIA:

Birch River, Bluefield, Buckhannon, Charleston, Clay, Cool Ridge, Cornstalk, Ellison, Gassaway, Grafton, Huntington, Marlinton, Pax, Prenter, Saint Marys, Shady Spring, and Wayne.

INTENSITY IV IN VIRGINIA:

Amelia Court House (3 miles south of), Amherst, Appomattox, Bland, Buckingham, Cleveland, Cumberland, Grundy, Halifax, Hanover Court House, Hillsville, Independence, Lexington, Lunenburg, Marion, Martinsville, New Castle, Richmond, Rustburg (6 miles east of), Salem, Staunton, and Stuart.

INTENSITY IV IN GEORGIA:

Augusta, Clarkesville, Cumming, Decatur, Greensboro, Haddock (1.2 miles north-east of), Hiawassee, Jefferson, Lexington, Toccoa, and Watkinsville (2½ miles south of).

INTENSITY IV IN KENTUCKY:

Frenchburg, Inez, Jackson, Louisa, Maysville, Owenton, Owingsville, Prestonsburg, Sandy Hook, Stanton, and West Liberty.

INTENSITY IV IN NORTH CAROLINA:

Asheville, Bakersville, Brevard, Danbury, Durham, Ellerbe, Fletcher, Greensboro, Haydenville, Morgantown, Raleigh, Reids-

ville, Selma, Statesville, Sylva, Waynesville, and Winston-Salem.

INTENSITY IV IN SOUTH CAROLINA:

Abbeville, Anderson, Camden, Chesterfield, Edgefield, Greenville, Greenwood, Kershaw, Lancaster, Laurens, Newberry, Rock Hill, Saluda, Spartanburg, and York.

INTENSITY IV IN TENNESSEE:

Blountville, Elizabethton, Greeneville, McKenzie, Martin, Memphis, Morristown, Mountain City, Newport, Rogersville, and Sneedville.

INTENSITY IV IN OHIO:

Cincinnati, Gallipolis, Jackson, and Portsmouth.

INTENSITY I-III IN WEST VIRGINIA:

Elizabeth, Greenville, Hamlin, Madison, Parsons, Piedmont, Ripley, Sarton, Sharon, Spencer, Streeter, Wayside, and Weston.

INTENSITY I-III IN VIRGINIA:

Bedford, Culpeper, Eggbornsville, Farmville, Harrisonburg, Jonesville, Lovington (1 mile west of), Palmyra, Petersburg, Roanoke, and Spotsylvania.

INTENSITY I-III IN GEORGIA:

Albany, Athens, Atlanta, Blairsville, Canton, Carnesville, Clayton, Dacula, Dallas, Gainesville, Hartwell, Madison, New Holland, Rutledge, and Shady Dale.

INTENSITY I-III IN KENTUCKY:

Barbourville, Beattyville, Booneville, Hyden, Leburn, Manchester, Morehead, Shelbyville, and Whitesburg.

INTENSITY I-III IN NORTH CAROLINA:

Boone, Bryson City, Cornelius, Franklinton, Littleton, Matthews, Murphy, Pineville, Staley, Timberlake, and Whittier.

INTENSITY I-III IN SOUTH CAROLINA:

Aiken, Chester, Columbia, and Piedmont.

INTENSITY I-III IN TENNESSEE:

Dandridge, Maynardville, and Rutledge.

INTENSITY I-III IN OHIO:

Athens, Chillicothe, Dayton, and Marietta.

INTENSITY I-III IN MARYLAND:

West Hyattsville.

December 11: 18:44:39.2*. Epicenter

37.8° north, 77.4° west, Virginia, W. V. Felt over approximately 3,500 square miles, principally in the Richmond area. At Richmond, press reported police, civil defense, and news media were flooded with calls. Window broke. Furniture moved about in the city and in surrounding areas. Intensity V effects were also noted at Ashland and King William (2½ miles east of). Intensity IV at Colonial Heights, Hanover, King and Queen Court House, New Kent, and Petersburg. Intensity I-III at Amelia Court House (3 miles south of), Chesterfield, Hopewell, and Spotsylvania.

December 13: 05:19:34.3*. Epicenter 35.1° north, 83.0° west, North Carolina, W. V. Felt over approximately 3,500 square miles of western sections of North and South Carolina. At Glenville, N.C., felt by and awakened all in community; frightened few. Sound like sonic boom was heard. At Pickens, S.C., felt by and awakened many in community; frightened few. Windows, doors, and dishes rattled slightly. Moderate rumbling earth noises. Intensity IV effects at Franklin, N.C., and at Anderson, Greenville, Greer, and Slater, S.C. Intensity I-III at Asheville, Brevard (south of, Rosman Tracking Station), Columbus, and Sylva, N.C.

CENTRAL REGION

[90th Meridian or Central Standard Time]

January 1: 17:35:36.2*. Epicenter 34.8° north, 92.6° west, central Arkansas, W. Magnitude 4.2. VI. Felt over approximately 23,000 square miles of northern and central Arkansas, several places in southern Missouri, and at Memphis, Tenn. (see fig. 5). Press reports indicated walls and floors cracked and dishes broke at Little Rock and North Little Rock, Ark. Only one report of plaster cracking was received through the questionnaire canvass. Man at North Little Rock said it was difficult to stand up. Explosivelike effects reported.

INTENSITY VI IN ARKANSAS:

Little Rock and North Little Rock.—

(Press) State police reported walls and floors cracked and dishes broke. At North Little Rock, a state trooper said it was difficult to stand up. He reported that lights were knocked out in western North Little Rock for 2-3 seconds, and that there were reports of some telephones being knocked out in southwestern Little Rock. Telephone company reported there was no damage to its facilities. Others reported: "Bed 'tried to walk' across the room, walls shook, and I thought the windows were going to fall out." Woman in southwest area said it sounded as if a train were running over the house or under the floor; rumbling noise; venetian blinds waved back and forth. Man thought his house had been hit by a car or that it was an explosion; lasted 30 seconds. Woman reported a clock stopped; house rocked for 1 minute.

Little Rock.—Felt by and frightened many. Plaster cracked. Small objects shifted, overturned, and fell; furniture shifted. Loud earth noises. Woman in a 10-story concrete building said it felt like the building swayed back and forth with large movement; mirrors swung on ninth floor.

INTENSITY V IN ARKANSAS:

Augusta, De Witt, Fordyce, Forrest City, Hazen, Huntsville, Morrilton, Mountain View, and Newport.

INTENSITY IV IN ARKANSAS:

Arkadelphia, Bald Knob, Batesville, Benton, Blytheville, Brinkley, Camden, Clarendon, Conway, Corning, Cummins Prison Farm (eastern Arkansas), Harrison, Helena, Lake Village, Lonoke, Marianna (9 miles north of), Marked Tree, Marshall, Prescott, Rogers, Sheridan, Stuttgart, Van Buren, and West Memphis.

INTENSITY IV IN MISSOURI:

Brandsville and Gainesville.

INTENSITY IV IN TENNESSEE:

Memphis (two tremors, 17:32 and 17:57).

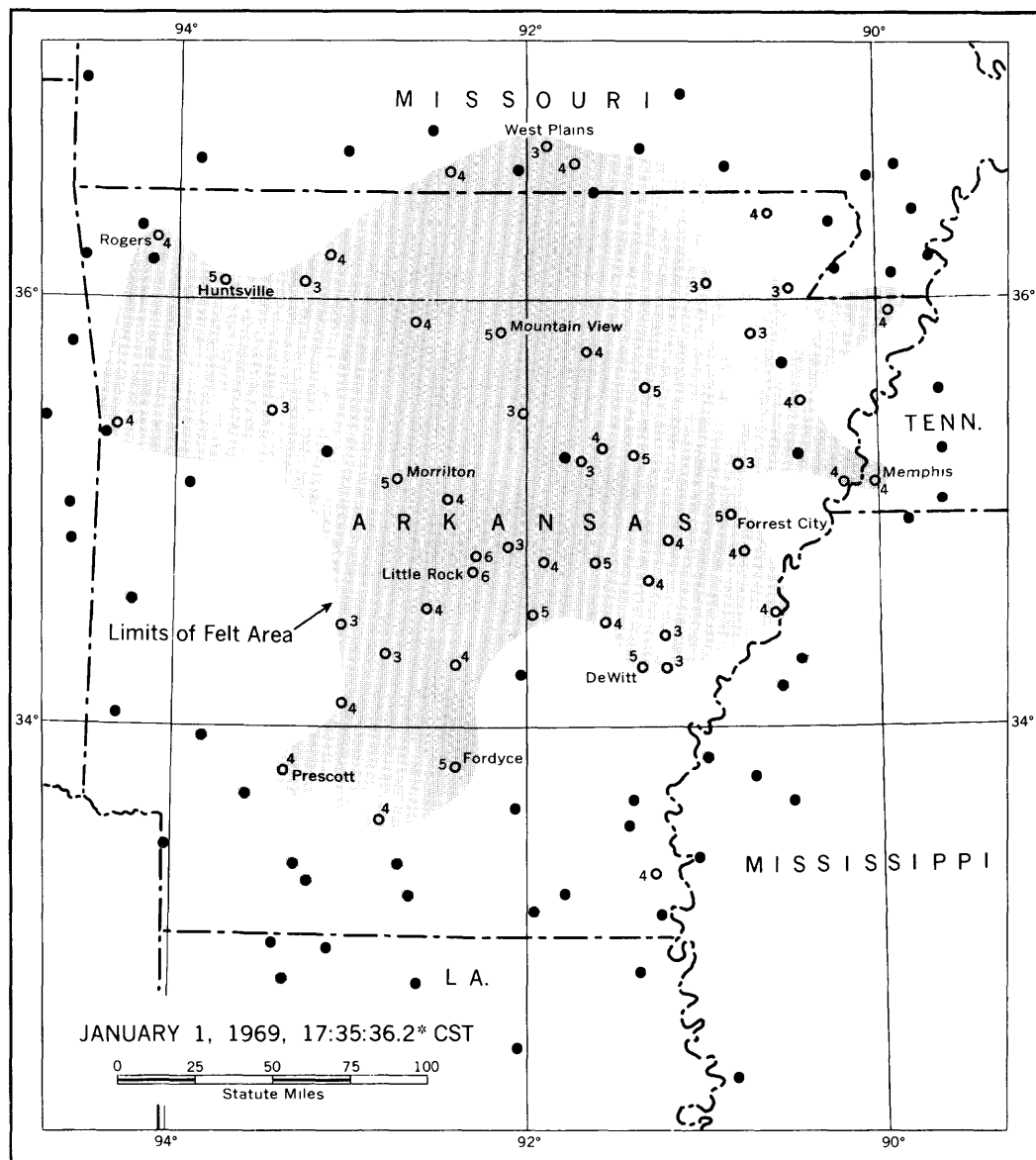


FIGURE 5.—Area affected by central Arkansas earthquake of January 1.

INTENSITY I-III IN ARKANSAS:

Clarksville, Compton, Cotter (second shock about 30 minutes later), Crocketts Bluff, England (two shocks), Ethel, Heber Springs, Hot Springs National Park, Jacksonville (2½ miles east of, on Highway 294), Jonesboro, Malvern, Paragould, Searcy (5 miles east of), Walnut Ridge, and Wynne.

INTENSITY I-III IN MISSOURI:

Sainte Genevieve and West Plains (shock felt about 2 minutes later).

January 20: 13:25 (about). Fredericktown, Mo. (Press) Residents reported feeling a small tremor, lasting about 8 seconds. Man at radio station said he felt the shock and that people called to report feeling it. St. Louis University reported the epi-

center was about 75 miles south of St. Louis in the Farmington-Doe Run area, and the magnitude was 2.5–3.0.

May 2: 05:33:19.8*. Epicenter 35.2° north, 96.3° west, Oklahoma, W. Magnitude 4.6. V. Felt over approximately 13,000 square miles of eastern Oklahoma (see fig. 6). Plaster cracked at Wewoka; small objects shifted at a few places. Intensity V also noted at Chandler, Crowder, Dustin, Henryetta, Holdenville, Indianola, Lamar,

Okemah, Savanna, Seminole, and Yeager. Intensity I–IV reported at several towns.

May 12: 02:26:18.7*, 02:49:16.3*, 02:51, and 04:39. Epicenter 31.8° north, 106.4° west, Texas-Mexico border region, W. Magnitudes of first two shocks, 3.4 and 3.3, respectively. VI. One house was damaged at El Paso (hairline cracks on ceiling and cracks on cement driveway). Also felt at Newman (IV).

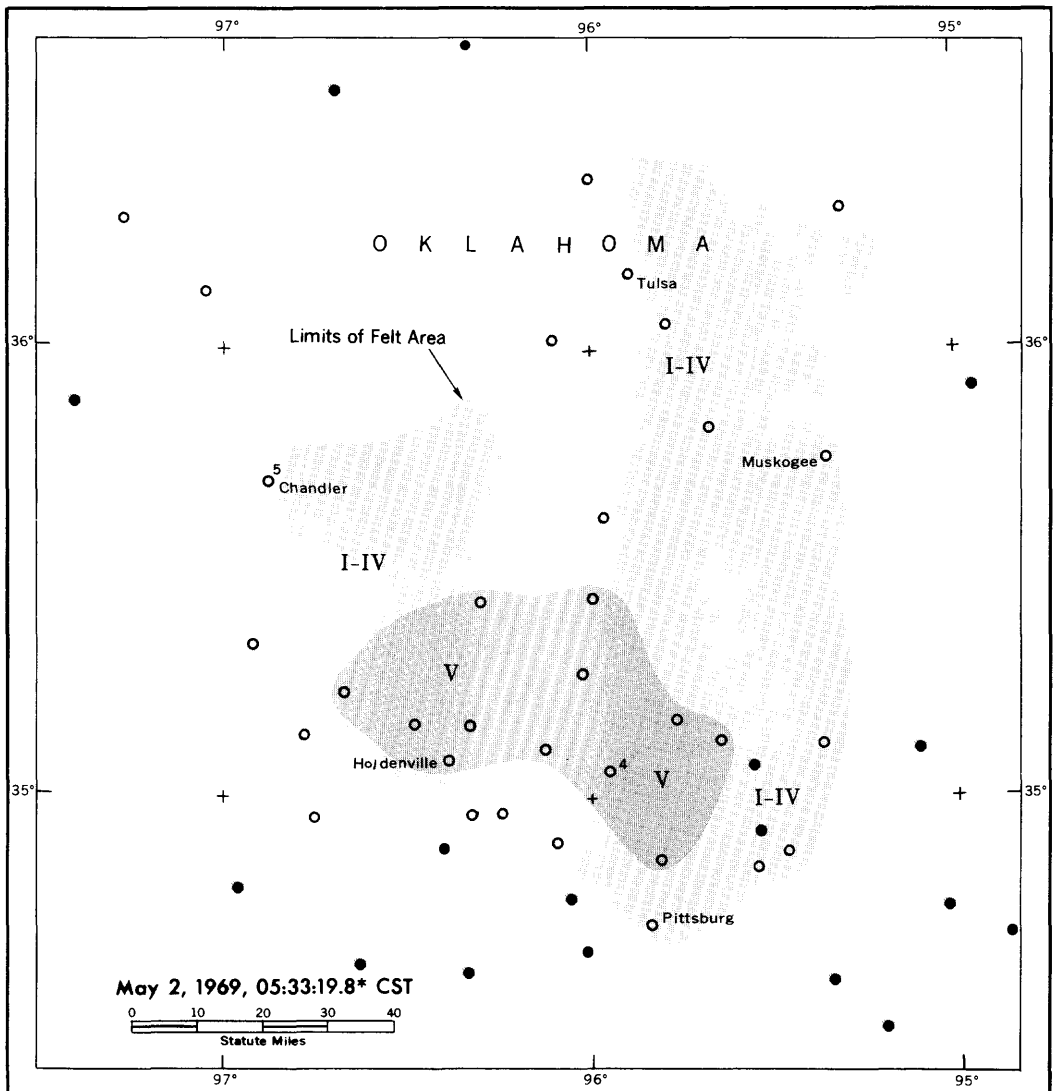


FIGURE 6.—Area affected by Oklahoma earthquake of May 2.

WESTERN MOUNTAIN REGION

[105th Meridian or Mountain Standard Time]

January 5: 23:34:14.5*. Epicenter 37.3° north, 116.5° west, southern Nevada, W. Magnitude 4.6. Felt.

January 23: 16:10:36.3*. Recorded at Salt Lake City. Magnitude 2.0–2.5 (University of Utah). Felt at Salt Lake City (press).

January 29: 22:17:37.8*. Epicenter 34.3° north, 106.9° west, New Mexico, W. Magnitude 4.1. **V.** Small cracks in poor adobe at Lajoya were enlarged. New cracks appeared in adobe at Alamillo. Also felt at Bernardo, Boys Ranch, Contreras, Lemitar, Polvadera (**V**), San Acacia (**V**), and Socorro. Field investigation made by Prof. A. J. Budding of the New Mexico Institute of Mining and Technology; questionnaire canvass made by Prof. Stuart A. Northrop, University of New Mexico.

February 16: 04:29:55.2*. Recorded at Salt Lake City. Magnitude 3.0–3.4 (University of Utah). Intensity **IV** at Salt Lake City (press).

April 1: 09:45:09.1* (main shock of series). Epicenter 47.9° north, 114.3° west, northwestern Montana, W. Magnitude 4.7. **VII.** Felt over about 10,000 square miles, principally in the Big Arm-Dayton-Proctor area along the southwest shore of Flathead Lake (see fig. 7). At Big Arm, the shock shifted a building several inches, buckled a boathouse, damaged a dock, and muddied well water. Four chimneys were lost at Dayton. At Proctor, a chimney broke and twisted, windows broke, and some deep wells increased in flow. Chimneys cracked, paneling loosened, concrete floor cracked, and water was disturbed at Lake Mary Ronan. Prof. S. W. Nile of the Montana School of Mines collected most of the important details through personal interviews. Approximately 41 aftershocks, all of less intensity than the main shock, were felt in the area from April 1 to 24. The strongest, on April 5 at about 17:18, was intensity **V** at Lake Mary Ronan.

INTENSITY VII:

Big Arm.—Felt by all. The southeast corner of one shop moved 1 inch north and 4 inches west. One block east, the center posts moved out of the beach, causing a boathouse to buckle; both ends were lower than the middle by 8 to 10 inches, and the dock was damaged. One observer noted, "Our well water became muddy, but cleared by next morning." At a ranch between Big Arm and Elmo, horses stampeded through a corral fence; the rails were splintered, according to press reports.

Dayton.—Four chimneys were destroyed. Owner of one of these said it was so loosened one could lift out any brick in it. A hot water heater broke and water leaked out. Merchandise fell from store shelves; pictures fell from wall; woodpile stacked against building fell over.

Lake Mary Ronan (about 5 miles northwest of Proctor).—Felt by and frightened all. Chimneys cracked, paneling loosened, hanging objects swung violently. Water was disturbed. "Concrete on first floor is all cracked—water seeping in; two new natural springs opened, one on each side of first floor."

Polson (5 miles north-northwest of, near western edge of highway toward Big Arm).—A resident at Big Arm reported a well became dry.

Proctor.—Felt by and frightened all. "Thought building would collapse." Old-fashioned school bell jumped loose from its moorings and fell to belfry floor. One window practically exploded at the school, another cracked. The large brick chimney broke off at roof; it did not fall, but the upper portion was twisted. The balance of the chimney was not damaged. In the Proctor store, a scale platform weighing about $7\frac{1}{2}$ pounds rose vertically at least $\frac{3}{4}$ inch, escaping from its supports. Well-water disturbances were noted at several wells in the area. Some increased in flow or became muddy and roily.

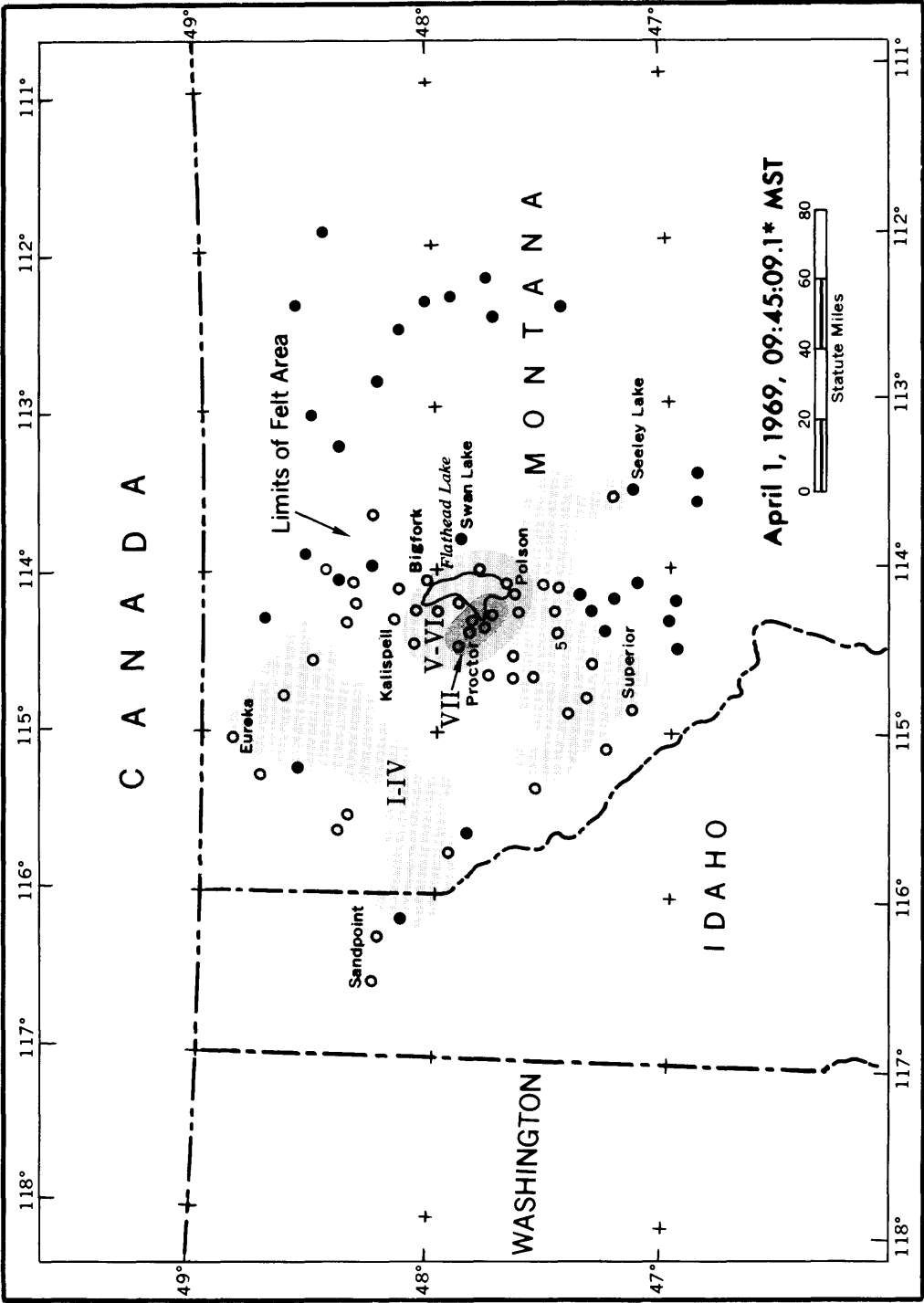


FIGURE 7.—Area affected by northwestern Montana earthquake of April 1.

INTENSITY VI:

Elmo.—Felt by all and frightened many. Small objects overturned and fell. Hanging objects swung violently. Trees and bushes shook; vehicles rocked. Moderate earth noises.

Emmett (near Kalispell at north end of Flathead Lake).—A chimney was reported to have toppled.

Kerr Dam.—Prof. S. W. Nile reported after a personal inspection: "Plaster had many small cracks and some hairline cracks in walls and ceilings with some larger cracks in corners. Plaster also cracked in other homes nearby."

Polson (south end of Flathead Lake).—Felt by all and frightened few. Press reported a chimney fell from house. Merchandise rattled, but none fell from shelves. Plate glass windows waved noticeably. Some people became dizzy and nauseated.

Rollins.—Felt by many and frightened few. South of Rollins, a chimney was reportedly lost. Small objects shifted. Loud rumbling earth noises.

Somers.—Garage ramp, oriented north-south, had a crack across ramp running approximately northeast-southwest. Loud earth noises. Building creaked for at least 25 seconds.

INTENSITY V:

Finley Point and Junction of Finley Point Road (southeast shore of Flathead Lake), Kila, Lakeside, Mahoney (about 10 miles west of Ronan), and Yellow Bay (east shore of Flathead Lake).

INTENSITY IV:

Brown, Columbia Falls, Hot Springs, Hungry Horse, Kalispell, Lonepine, Niarada, Olney, Pablo, Paradise, Perma, Ronan, Seeley Lake area, Stryker, Superior, and Trout Creek (7 miles northwest of, on U.S. Highway 20).

INTENSITY I-III:

Bigfork, Creston, Essex, Eureka, Kootenai Gardens, Libby, Plains, Round Butte, Thompson Falls, and Whitefish.

INTENSITY I-III IN IDAHO:

Hope and Sandpoint.

April 17: 09:49. Denver, Colo., region. Magnitude 2.5 (Golden). Intensity IV at Commerce City, Northglenn, and Thornton.

April 22: 06:24:02.6*. Epicenter 44.2° north, 114.6° west, western Idaho, W. Magnitude 3.6. Intensity IV at Clayton.

April 26: 03:41:53.0*. Epicenter 44.2° north, 114.5° west, western Idaho, W. Magnitude 4.9. VI. Felt over about 9,000 square miles of Idaho and at one town in Oregon. Cement basement floor cracked at Ketchum; cement floor of living room cracked at nearby Warm Springs.

INTENSITY VI:

Hailey-Ketchum area.—Many were awakened and frightened. Press reported minor damage in this area, including a cracked basement floor at Ketchum.

Livingston Mill (about 12 miles south of Clayton).—Felt by, awakened, and frightened all in building. Damage slight. Plaster cracked; glass fell from cupboard onto floor. Loud rumbling earth noises.

Warm Springs.—Buildings swayed visibly. Cement floor of living room cracked; pictures on stand displaced. Disturbed objects noted by several.

INTENSITY V:

Atlanta, Challis, Clayton and vicinity, Fairfield, Greenleaf, Hill City, Obsidian, Salmon River area and East Fork of Salmon River, Stanley, Sunbeam Resort (about 10 miles northeast of Stanley), Sun Valley, and Sweet.

INTENSITY IV:

Bellevue, Boise, Mackay, Meridian, and Picabo.

INTENSITY I-III:

Arco, Caldwell, Eagle, Gooding, and Nampa.

INTENSITY I-III IN OREGON:

Ontario.

April 27: 15:15. Light shake at Big Arm, Mont.

April 28: 04:40. Proctor, Mont. V. Felt

by all in community. Moderate earth noises at time of shock.

April 30: 20:10:23.8*. Epicenter 46.7° north, 112.8° west, northwestern Montana, W. Magnitude 3.9. **V**. Probable felt area on the order of 3,000 square miles. Prof. Stephen W. Nile travelled the route from Missoula to Lincoln, making inquiries at various communities. He reported that, in general, the shock was most strongly felt at Lincoln and in the Rogers Pass area. Intensity **IV** at Helena, Ovando and 2½ miles northeast of, and near Rogers Pass. Intensity **I-III** at Great Falls, Greenough, Missoula, and Ovando (4 miles east of).

May 1: 15:30. Light tremor at Big Arm, Mont.

May 3: 02:30. Felt at Ketchum, Idaho.

May 3: 12:25. Intensity **IV** at Big Arm, Mont.

May 4: 14:58 and 17:30. Rumble and light tremor at Big Arm, Mont.

May 5: 00:09:10.9*. Epicenter 44.1° north, 114.5° west, western Idaho, W. Magnitude 4.6. **V**. Awakened many in community at Clayton; few frightened. Windows, doors, and dishes rattled; moderate earth noises. "Also felt by many along the Salmon River. Shock followed by a slight rumble several minutes later."

May 5: 17:05. Intensity **IV** at Big Arm, Mont.

May 6: 06:40. Proctor, Mont. **V**. Felt by all in community. Loud earth noises. Windows and dishes rattled. Also felt at Dayton.

May 6: 18:40 and 18:50. First shock intensity **IV** at Big Arm, Mont. Loud rumble from south 10 minutes later. Some also felt a tremor during the night.

May 8: 16:00. May 9: 05:00. May 11: 10:00. Felt at Dayton, Mont.

May 13: 11:40 and 13:45. Rumbles felt at Big Arm, Mont.

May 21: 01:45. Intensity **IV** at Big Arm and Proctor, Mont.

May 23: 02:00:53.5* and 03:43. Commerce City, Colo., area. Magnitudes 3.3

and 2.8, respectively (Golden). **V**. In Commerce City and vicinity, many were awakened, few frightened. Rock in garden fell to west; objects shifted in bookcase. Loud rumblings before shock.

May 25: 18:30:08.6*. Epicenter 40.4° north, 104.4° west, Colorado, W. Magnitude 3.5 (Golden). Intensity **IV** at Commerce City and Denver.

May 28: 06:00. May 31: 16:00. June 6: 10:00. June 8: 16:00. Small shocks felt at Dayton, Mont. June 6 shock intensity **IV**.

June 9: 01:53:30.8*. Epicenter 47.9° north, 114.3° west, Montana, W. Magnitude 4.2. **V**. Felt over 3,500 square miles of northwestern Montana, principally in the southwest Flathead Lake area. No damage reported. Intensity **V** at Big Arm, Coster's Point, Dayton, Elmo, Lake Mary Ronan Lodge (6.3 miles northwest of Proctor), Polson, Proctor, Rollins, and Somers. Intensity **IV** at Bigfork, Coram, Hot Springs, Hungry Horse, Kila, Lakeside, Lonepine, Ronan, and Round Butte and Sloan Bridge areas west of Ronan. Intensity **I-III** at Columbia Falls, Creston, Kalispell, and Swan Lake.

June 9: 02:00. Light rumble at Big Arm, Mont.

June 9: 02:30. Intensity **III** shock at Rollins, Mont.

June 9: 03:45. Intensity **IV** at Big Arm, Mont.; intensity **III** at Dayton.

June 9: 08:47:14.8*. Epicenter 47.9° north, 114.4° west, Montana, W. Intensity **IV** at Big Arm. Also felt at Dayton and Rollins. Aftershock at 11:16 felt at Rollins; shocks at 11:20, 13:52, 14:07, and 20:25 felt at Big Arm.

June 10: 10:26 and 14:00. Felt at Big Arm, Mont.

June 11: 06:03:57.1*. Epicenter 47.9° north, 114.2° west, Montana, W. Magnitude 4.1. Intensity **IV** at Big Arm. Fore-shock (intensity **IV**) felt at 04:12; light aftershocks felt at 07:06, 08:50, 14:03, and 18:43. Aftershocks also reported felt at Big Arm on June 12 at 09:15, 11:17, 20:45, and

21:35; on June 13 at 21:27; and on June 14 at 05:20.

June 14: 10:13. Felt at Proctor, Mont.

June 16: 03:03. June 17: 03:25. Felt at Proctor, Mont.

June 17: 13:10. Light rumble at Big Arm, Mont.

June 18: 10:39. Felt at Proctor, Mont.

June 21: 03:29, 03:30, 04:06:48.8*, and 04:18. Epicenter of third shock 47.9° north, 114.5° west, Montana, W. Magnitude 3.1. V. Felt by all and awakened few at Proctor. Sharp shock, with loud earth noises. Shocks at 03:29, 03:30, and 04:18 were light. "There have been several shocks prior to these, but not worth mentioning. Shocks are getting commonplace."

June 24: 19:16:00.8*. Epicenter 47.9° north, 114.3° west, Montana, W. Magnitude 3.8. Mild tremor felt at Big Arm.

June 25: 04:35:54.3*. Epicenter 48.0° north, 114.3° west, Montana, W. Magnitude 4.3. Intensity IV at Big Arm.

June 29: 16:45. Felt at Big Arm, Mont.

July 1: 01:48, 9:04 (a.m. or p.m. not given), and 10:40 (a.m. or p.m. not given). All felt at Big Arm, Mont. The first shock was intensity III.

July 4: 07:43:34.0*. Epicenter 36.1° north, 106.1° west, New Mexico, W. Magnitude 4.4. Intensity IV at Espanola (6 miles north of and 11 miles north of), Fairview area, and San Juan Pueblo (corner of Chama and Ojo Caliente Highways).

July 30: 09:45, 11:15, and 11:16 (a.m. or p.m. not given). All were felt at Big Arm, Mont. The first shock was also reported felt at Dayton.

July 31: 22:45. August 1: 05:30. Press reported both shocks felt at Dayton, Mont.

August 3: 05:57:35.6*. Epicenter 47.8° north, 114.2° west, Montana, W. Mild shock felt at Dayton.

August 27: 08:59:28.4*. Epicenter 42.9° north, 110.8° west, western Wyoming, W. Magnitude 4.2. Intensity III at Auburn.

August 27: 11:00 and 12:56. The first shock was intensity IV at Proctor, Mont.

Second shock seemed "farther away and from westerly direction."

August 29: 06:04 and 12:02. August 30: 15:15. The first shock was intensity IV at Big Arm, Mont. Loud rumbles accompanied later shocks.

September 13: 04:25 and 05:14. Commerce City, Colo. Magnitudes 2.6 and 2.4, respectively (Golden). Both shocks were intensity III.

September 14: 05:15, 09:15, and 11:27. The first two shocks were felt at Big Arm, Mont.; the first and third at Dayton; the third at Lake Mary Ronan.

September 14: 17:02:39.0*. Epicenter 47.9° north, 114.2° west, Montana, W. Magnitude 4.3. VI. Felt over 2,000 square miles, principally in the Big Arm-Dayton-Proctor area of southwest Flathead Lake. A basement wall and building corner sustained cracks at Big Arm.

INTENSITY VI:

Big Arm.—Felt by all. Crack, running in both horizontal and vertical directions, in northeast corner of building. Press reported a basement wall cracked. Loud, explosive-like rumbling.

INTENSITY V:

Dayton, Proctor, Rollins, and Ronan.

INTENSITY IV:

Elmo, Kalispell, Polson, and Somers.

INTENSITY I-III:

Kila, Lakeside, Lonepine, and Swan Lake.

September 14: 20:22:41.0*. Epicenter 47.9° north, 114.2° west, Montana, W. Magnitude 4.0. Intensity IV at Big Arm, Kalispell, Polson, Proctor, and Rollins. Also felt at Dayton.

September 15: 08:00. Felt at Big Arm and Rollins, Mont.

September 16: 08:00. Intensity IV at Big Arm, Mont.

September 17: a.m. Felt at Rollins, Mont.

September 22: 16:18 and 18:25. September 27: 18:22. Shocks felt at Big Arm, Mont.

September 28: 17:00 and 20:15. Felt at Big Arm, Mont. The second shock was intensity IV.

October 3: 00:15. Intensity III at Big Arm, Mont.

October 7: 08:11. Flathead Lake area, Mont. V. Felt by all in community at Proctor. Small objects shifted. Loud earth noises. Also felt at Big Arm.

October 13: 22:15:54.0*. Epicenter 47.8° north, 114.2° west, Flathead Lake area, Mont., W. Magnitude 4.4. V. Felt by all and awakened many in community at Proctor. Very loud, explosivelike earth noises. Intensity IV at Big Arm. Also felt quite strongly at Rollins.

October 14: 10:40. October 28: 21:30. October 30: 07:35. All were felt at Big Arm, Mont. Loud rumbles heard.

November 4: 23:01, 23:04, and 23:11. Flathead Lake area, Mont. Three sharp shocks jolted the west shore of Flathead Lake. At Elmo, the first and third jolts were much stronger than the second. Also felt at Proctor.

November 6: 16:00. Felt at Big Arm, Mont. Loud rumble from southwest.

November 6: 17:11:29.1*. Epicenter 47.9° north, 114.2° west, Flathead Lake area, Mont., W. Magnitude 4.3. VI. Felt by all and frightened few in community at Dayton. Plaster fell. Small objects shifted, overturned, and fell. Damage slight. Loud earth noises. Intensity V effects at Big Arm and Elmo. Intensity IV at Polson, Proctor, and Rollins. Intensity II at Lakeside.

November 7: 18:25. November 12: 10:25. November 24: 09:34. All were felt at Big Arm, Mont. Rumbles heard.

December 12: 13:15. Felt at Big Arm, Mont. Loud rumble from southwest.

December 12: 20:19. December 21: 19:44. Both were intensity IV at Big Arm Mont.

December 25: 05:49:10.1*. Epicenter 33.4° north, 110.6° west, eastern Arizona, W. Magnitude 4.4. Felt at Globe and Cutter.

December 25: 22:28:33.8*. Epicenter 48.0° north, 114.1° west, Flathead Lake area, Mont., W. Intensity IV at Big Arm.

December 26: 18:45. December 29: 10:50. Both were felt at Big Arm, Mont. Loud rumbles heard.

CALIFORNIA AND WESTERN NEVADA

[120th Meridian or Pacific Standard Time]

NOTE: All towns mentioned are in California unless otherwise stated.

January 9: 01:42:46.6*. Epicenter 36.0° north, 120.6° west, central California, W. Magnitude 3.7, B. V. Plaster cracked slightly at Slack Canyon, 20 miles northwest of Parkfield; a window broke 7 miles north-northwest of Parkfield. Intensity IV at Parkfield and 7 miles southeast of, San Miguel, and Work Ranch (15 miles northeast of San Miguel).

January 10: 11:00, 12:00, and 13:30 (about). Intensity IV at Parkfield.

January 13: 08:23:47.9*. Epicenter $33^{\circ}59.2'$ north, $116^{\circ}52.7'$ west, southern California, P. Magnitude 3.5. Intensity V at White Water, but no damage was sustained. Intensity IV at Cathedral City, Idyllwild, Morongo Valley, Palm Springs, Piñonville, Rancho Mirage, and Yucca Valley.

January 14: 20:28:09.2*. Epicenter $38^{\circ}31'$ north, $122^{\circ}42.3'$ west, northern California, B. Magnitude 3.0. Intensity IV at Fulton (southwest of) and Santa Rosa. Also felt at Calistoga.

January 17: 10:50. January 20: 15:05. Shocks were reported felt at Anza.

January 23: 15:01:01.0*. Epicenter $33^{\circ}53.2'$ north, $116^{\circ}02.4'$ west, southern California, P. Magnitude 4.8. V. Felt over 5,000 square miles, principally in Riverside and San Bernardino Counties. Although no damage occurred, intensity V effects were noted at Coachella, Hayfield Pumping Plant (west of Desert Center), Indio, North Palm Springs, North Shore, Palm

Desert, Palm Springs, Thermal, Thousand Palms, and Twenty-nine Palms. Intensity IV at Anza, Chiriaco Summit, Coyote Canyon, Desert Center, Eagle Mountain, Idyllwild, Joshua Tree, La Quinta, Marine Corps Base (north of Twenty-nine Palms), Morongo Valley, Mountain Center, Pinon Crest (Nightingale), Pioneertown, and Sky Valley (north of Thousand Palms). Intensity I-III at Desert Hot Springs, Forest Falls, Hemet (east of), Julian (Pine Hills), Riverside, Salton City, San Jacinto, Santa Ysabel, and Yucca Valley.

January 24: 19:00:04.0*. Epicenter $33^{\circ}50'$ north, $115^{\circ}59'$ west, southern California, P. Magnitude 4.1. Aftershock of January 23. Intensity IV at Palm Springs.

January 24: 22:04:58.7* and 22:12. Epicenter $34^{\circ}01.8'$ north, $116^{\circ}30.9'$ west, southern California, P. The first shock was intensity IV at Morongo Valley; both were felt at Palm Springs.

January 28: 12:57 and 22:35. January 31: 02:16. Three shocks were felt at Ferndale with intensities IV, III, and II, respectively.

February 7: 13:25:45.4*. Epicenter $40^{\circ}22'$ north, $124^{\circ}30'$ west, near coast of northern California, off Cape Mendocino, B. Magnitude 4.6. VI. Felt over 4,000 square miles of Humboldt, Mendocino, and Trinity Counties. One tombstone fell, one twisted, and several small cracks appeared in walls of school building at Ferndale. Ceiling plaster cracked at Honeydew. At Petrolia, chimneys twisted and landslides occurred. Much merchandise was broken in Rio Dell and Scotia stores. Berkeley reported more than 40 aftershocks, the largest magnitude 2.8.

INTENSITY VI:

Ferndale.—Felt by all and frightened many. Several small cracks in wall noted in old part of elementary school. Large clock stopped at seismograph station. Jars of food fell at ranch. Hanging objects swung violently.

Honeydew.—Felt by all and frightened

many. Ceiling plaster cracked. Small objects shifted and fell. Building seemed to move up and down.

Petrolia.—Felt by and frightened all; some students at school panicked. Chimneys twisted; landslides were reported. Many items were knocked from shelves. School bell rang once. Cabinet and closet doors, with magnetic latches, all came open; contents shifted or fell. Very violent on ranch 8 miles east of Petrolia.

Rio Dell.—Felt by and frightened many. Merchandise fell and broke in nearly every store. Slight damage.

Scotia.—Felt by all and frightened few. Some canned and bottled items fell in stores. Small objects shifted, overturned, and fell. Damage slight.

INTENSITY V:

Arcata, Bridgeville and 6 miles north of, Carlotta, Cutten, Eureka, Fields Landing, Freshwater, Garberville, Honeydew (near), Hydesville, Loleta, Maple Creek (about 10 miles south of Korbel), Miranda, Phillipsville, Redcrest, Redway, Rockport, Shelter Cove, Samoa, Westport, Whitethorn, and Yeager Valley area (about 8 miles north of Bridgeville).

INTENSITY IV:

Alderpoint, Bayside, Branscomb, Crannell, Fort Seward, Fortuna, Heart Creek (about 7 miles north of Branscomb), Kneeland, Korbel, Leggett, and Myers Flat.

INTENSITY I-III:

Blocksburg, Blue Lake, Burnt Ranch, Fort Bragg, Harris, Rabbit Camp (about 1 mile south of Humboldt County line), Weott, and Zenia.

February 7: 23:15. Intensity IV at Petrolia.

February 11: 07:22 (about). Intensity IV at Petrolia and Rio Dell.

February 14: 13:17. Intensity IV at Petrolia. Also felt at Alton, Ferndale, Rio Dell, and Scotia.

February 15: 09:30. Intensity IV in southwest section of Escondido.

February 21: 18:05:34.5*. Epicenter 40.7° north, 124.3° west, near coast of northern California, W. Magnitude 4.1. Felt at Ferndale.

February 22: 10:37:31.8*. Epicenter 40.6° north, 123.7° west, northern California, W. Magnitude 3.0, B. Intensity IV at Rio Dell. Also felt at Ferndale.

February 27: 20:56:12.4*. Epicenter 34°34' north, 118°07' west, southern California, P. Magnitude 4.3. VI. Felt over 4,800 square miles of southern California, principally in the Palmdale area of northern Los Angeles County. At Palmdale, fluorescent lights fell, windows broke, and telephone service was disrupted briefly.

INTENSITY VI:

Palmdale.—Scattered instances of broken windows were reported by the press. Two fluorescent lights fell from fixtures at the Sheriff's Substation. Telephone service was disrupted briefly, but no lines were down. Some pictures and other small objects fell. Loud, explosivelike earth noises.

INTENSITY V:

Acton (southwest of Palmdale; plaster cracked), Green Valley, Hidden Springs (southeast of Acton), Lake Hughes, Lancaster, Littlerock, Llano, and Pearblossom.

INTENSITY IV:

Altadena, Edwards Air Force Base, Helendale, Lancaster (13 miles northwest of), Los Angeles, Newhall, North Edwards, North Hollywood, Pasadena, Quartz Hill (northwest of Palmdale), Rosamond, San Fernando, Santa Susana, Saugus Power Plant No. 1 (17 miles northeast of Saugus), Sunland, Sun Valley, Tujunga, Valyermo, and Wrightwood.

INTENSITY I-III:

Alhambra, Azusa, El Mirage (west of Adelanto), El Monte, Fairmont Reservoir, George Air Force Base (near Adelanto), Glendora, La Canada, Mojave, Northridge, Sandberg area (about 13 miles southeast of Gorman), San Gabriel, Santa Monica, Topanga, Upland, and Woodland Hills.

February 28: 09:44. Intensity IV at Escondido.

March 5: 05:53:50.6*. Epicenter 34° 10.8' north, 117°20.3' west, southern California, P. Magnitude 3.4. Intensity IV at Etiwanda and San Bernardino. Also felt at Colton, Fontana, Redlands, Rialto, and Riverside.

March 11: 13:53:06.9*. Epicenter 34° 04.1' north, 119°10.7' west, near coast of southern California, P. Magnitude 2.5. Felt at Oxnard and Ventura.

March 12: 19:23:23.6*. Epicenter 38° 02' north, 121°51' west, northern California, near Antioch, B. Magnitude 3¾. V. Generally felt over 800 square miles, principally in northeastern Contra Costa County. Intensity V at Antioch, Pittsburg, and Port Chicago (plaster cracked). Intensity IV at Birds Landing (east of), Brentwood, Clayton, Collinsville (east of), Concord, Knightsen, Martinez, and Port Costa. Intensity I-III at Antioch (east of), Benicia, Berkeley, Bethel Island, Crockett, Daly City, Mill Valley, Oakland, Oakley, Pinole, Redwood City, Richmond, Rodeo, San Francisco, San Rafael, and South San Francisco.

March 14: 01:16:05*. Epicenter 41°15' north, 123°45' west, northern California, B. Magnitude 3.5. Felt at Ferndale and in Eureka-Arcata area.

March 16: 19:06:51.7*. Epicenter 34° 11.5' north, 117°21.1' west, southern California, P. Magnitude 3.3. V. Felt over approximately 1,600 square miles, principally in the Riverside-San Bernardino area, but no damage occurred. Intensity V at Bloomington, Lake Arrowhead, Lytle Creek, Patton, and Riverside. Intensity IV at Colton, Etiwanda, Fontana (north of), Highland, Moreno, Norco, Ontario, and Rialto. Intensity I-III at Alta Loma and Corona.

March 24: 05:43. Felt at Pit River Powerhouse No. 1, near Fall River Mills.

March 27: 20:53:37.0*. Epicenter 41° 02.7' north, 121°33.0' west, northern California, B. Magnitude 3.8. V. Felt over 600

square miles of Shasta County, but no damage was sustained. Intensity **V** near Cayton, at McArthur-Burney Falls State Park, and at Pit River Powerhouses Nos. 1 (near Fall River Mills) and 3 (near Burney). Intensity **IV** at Fall River Mills and Glenburn. Intensity **I-III** at McArthur.

March 28: 10:12:56.6*. Epicenter $41^{\circ}02.7'$ north, $121^{\circ}33.0'$ west, northern California, B. Magnitude 4.2. **V**. Felt over 1,200 square miles of Shasta County. No damage occurred, but a stack of lumber reportedly fell at Burney. Intensity **V** also noted at McArthur, McArthur-Burney Falls State Park (near Cayton), and Pit River Powerhouse No. 3 (near Burney). Intensity **IV** at Fall River Mills, Glenburn, and Pit River Powerhouse No. 1 (near Fall River Mills). Intensity **I-III** at Big Bend and Pit River Powerhouse No. 5 (near Montgomery Creek).

March 29: 00:28. Intensity **IV** at Nevada City. Also felt at Grass Valley (**III**).

March 29: No time given. Small shock felt at McArthur-Burney Falls State Park (near Cayton).

April 6: 06:11:40.3*. Epicenter $40^{\circ}37'$ north, $126^{\circ}14'$ west, off coast of northern California, B. Magnitude 4.3. Felt at Ferndale.

April 12: 09:13:03.0*. Epicenter $40^{\circ}52'$ north, $121^{\circ}44'$ west, northern California, B. Magnitude 3.3. Felt near Burney and Fall River Mills (Pit River Powerhouses Nos. 1 and 3).

April 13: 02:55:05.7*. Epicenter $33^{\circ}34'$ north, $118^{\circ}19'$ west, near coast of southern California, B. Magnitude 3.5. Felt at Long Beach.

April 13: 20:22:36.4*. Epicenter $37^{\circ}52.9'$ north, $122^{\circ}14.3'$ west, central California, B. Magnitude 3.0. Intensity **IV** at Berkeley, El Cerrito, Oakland, and San Francisco. Also felt at Orinda, Piedmont, and Richmond.

April 14: 06:26:06.2*. Epicenter $34^{\circ}08'$ north, $119^{\circ}10'$ west, southern California, P. Magnitude 3.3. No damage oc-

curred, but intensity **V** effects were noted at four locations in Oxnard; intensity **IV** in Port Hueneme. Also felt at Ventura.

April 14: 22:30. Intensity **III** at Ferndale.

April 23: 15:47:26.1*. Epicenter $37^{\circ}22.8'$ north, $121^{\circ}43.3'$ west, central California, B. Magnitude 3.3. Intensity **IV** at Palo Alto. Also felt at San Bruno and San Jose.

April 25: 03:45. Intensity **III** at Oakland.

April 26: 21:49:34.0*. Epicenter $34^{\circ}15'$ north, $118^{\circ}29'$ west, southern California, P. Magnitude 2.8. Felt at Hollywood.

April 28: 15:20:42.9*. Epicenter $33^{\circ}21'$ north, $116^{\circ}21'$ west, southern California, P. Magnitude 5.9. **VII**. Felt over approximately 30,000 square miles in the United States, principally in northeastern San Diego County at Borrego Springs and vicinity (see fig. 8). Large pieces of a ceiling fell, brick walls cracked, and light fixtures were damaged in a building at Borrego Springs. Huge boulders rolled down nearby slopes of the Santa Rosa Mountains; dust clouds could be seen up to 15 miles away. A two-lane highway was blocked by large boulders about 3 miles west of Borrego Springs. A Geological Survey team investigating the area reported no new ground breaks were found anywhere. Tall buildings swayed at Los Angeles and San Diego, and at Las Vegas, Nev., Yuma, Ariz., residents also reported the strong shock.

INTENSITY VII:

Borrego Springs.—A U.S. Geological Survey team reported that the ceiling in the First National Bank buckled, and the door of the vault would not close after the shock. Several saw dust clouds rising from the west slope of the Santa Rosa Mountains northeast of Clark Valley. Minor rockfalls occurred 2 to 3 miles west of Borrego Springs on the Montezuma-Borrego Highway. Press reports indicated some light fixtures were damaged and brick walls cracked

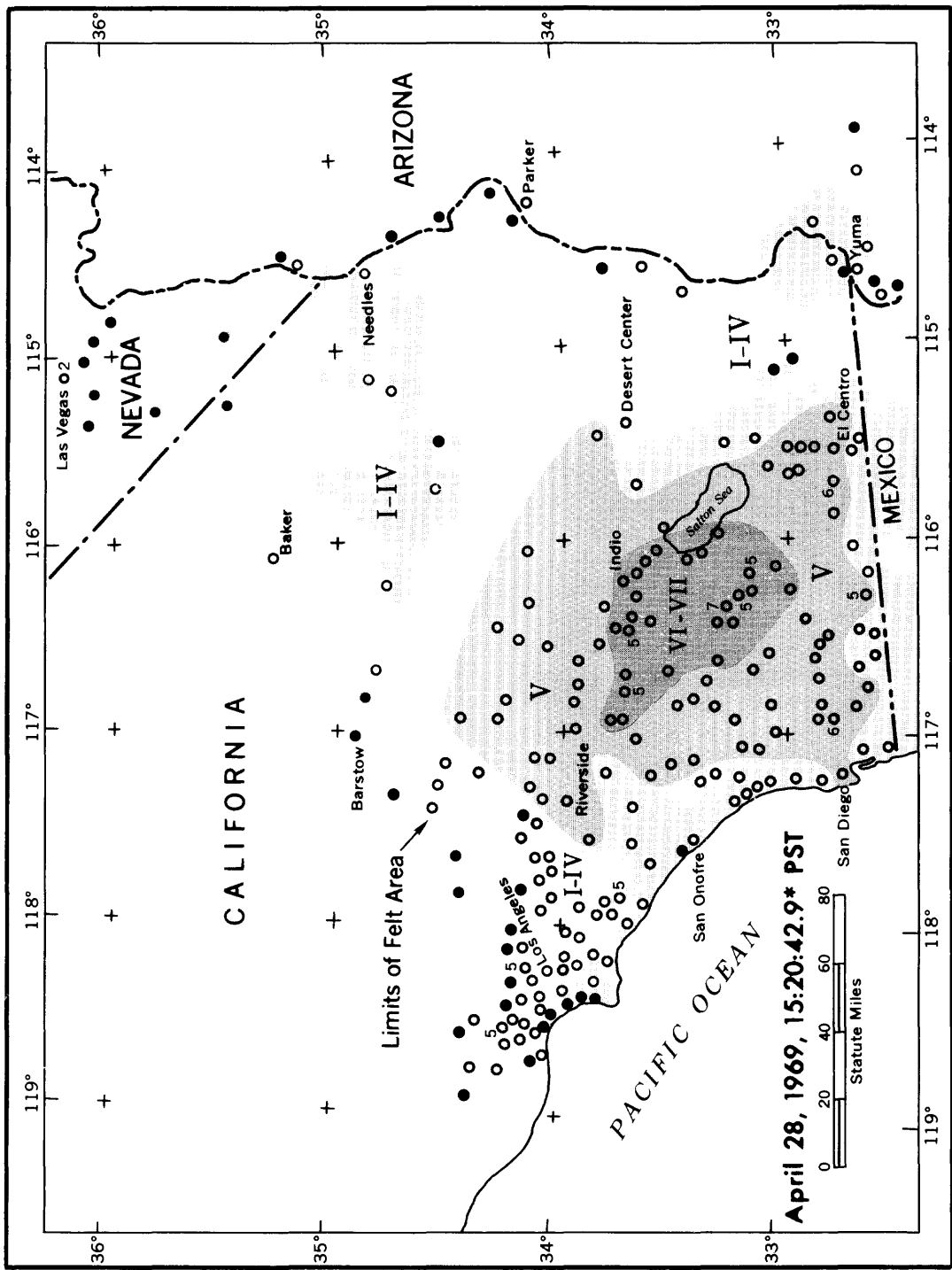


FIGURE 8.—Area affected by southern California earthquake of April 28.

at the First National Bank. Damage in stores amounted to about \$1,000.

Santa Rosa Mountains (northeast of Borrego Springs).—Press reported a gas station attendant observed giant boulders bounding down the mountains and large clouds of dust. Park rangers at the Anza-Borrego Desert State Park also reported large clouds of dust rising several hundred feet in the air above Coyote Mountain.

INTENSITY VI:

Agua Caliente (about 20 miles south of Borrego Springs).—Felt by all and frightened few. An 8-foot metal bookshelf swayed 4 to 5 inches back and forth. Trees and bushes shook. Hanging objects swung violently. Faint earth noises.

Anza-Borrego Desert State Park.—Felt by all and frightened many about 7 miles northwest of Borrego Springs. Windows cracked. Small objects fell. Rocks rolled down the hill about 10 miles south by east of Ocotillo Wells at Split Mountain. Trees and bushes shook.

Cathedral City.—Felt by all. Damage slight (no details). Furniture shifted. Trees and bushes shook. Hanging objects swung violently.

Coachella.—Felt by all and frightened many. Plaster cracked. Furniture shifted. Small objects fell in homes and stores. Trees and bushes shook.

Desert Ironwoods Motel (about 3 miles west of Ocotillo Wells and $\frac{1}{2}$ mile south of Highway 78).—Felt by all and frightened few. Water sloshed over side of swimming pool. Much dust visible from slides in Santa Rosa Mountains to the north.

El Cajon.—Felt by and frightened many. About \$75 damage to store merchandise reported by press. Furniture shifted. Trees and bushes shook. Hanging objects swung violently.

Hemet.—Felt by all. Plaster cracked. Small objects shifted. Hanging objects swung moderately.

Idyllwild.—Felt by all and frightened

many. Plaster cracked. Small objects overturned. Trees and bushes shook.

Indio.—Felt by all and frightened many. Waves noted on irrigation plot. Press reported power failure from high-voltage lines slapping together. Much damage in one supermarket.

La Quinta.—Felt by all and frightened many. Landslides noted. Plaster cracked. Furniture shifted. Hanging objects swung violently.

Mecca.—Felt by all and frightened many. Much damage in local markets. Dust and rolling rocks in nearby hills observed by many. Furniture shifted.

Palm Desert.—Felt by all and frightened many. Most violent shock observer ever experienced. Small objects fell. Trees and bushes shook. Press reported rocks fell on State Highway 74 south of Palm Desert, and issued a warning to motorists.

Salton City.—Felt by all; some frightened. Damage slight (no details). Water disturbed. Trees, bushes, and vehicles shook. Press reported minor leaks in water pipes. A brief power failure occurred at Oasis, about 15 miles northwest of Salton City.

San Jacinto.—Felt by all and frightened many. Damage slight. Plaster cracked. Bushes shook. Hanging objects swung violently.

Seeley.—Felt by and frightened all. Loud earth noises. Trees and bushes shook. Hanging objects swung violently.

Terwilliger Valley (southeast of Anza).—Felt by all and frightened few. No damage; only a few dents in cans. Building rocked a long time and creaked loudly. Bushes shook. Hanging objects swung violently. "It was like being on a boat, the ground moved so much."

Thermal.—Felt by all and frightened many. Plaster cracked in community. Small objects fell. Rocks rolled in the mountains. Trees and bushes shook.

Warner Springs.—Felt by all. Furniture shifted. Buildings creaked very loudly. Hanging objects swung moderately. Press

reported roads were closed by boulders that damaged the highway. Loud earth noises.

Wildomar.—Felt by and frightened all. Furniture shifted. Trees and bushes shook. Hanging objects swung violently. Loud, rumbling earth noises.

INTENSITY V:

Aguanga, Alpine, Beaumont, Borrego Air Ranch (northwest of Ocotillo Wells), Boulevard, Brawley, Cabazon, Calexico, Colton, Corona, Curtis (southeast of Aguanga), Descanso, Desert Shores (northwest shore of Salton Sea), Dulzura, Eagle Mountain, El Centro, Escondido, Fawnskin, Guatay, Holtville, Huntington Beach, Imperial, Jamul, Joshua Tree, Landers, Lucerne Valley, Moore Ranch (west of Brawley), Morongo Valley, Mountain Center, Northridge, North Shore (northeast shore of Salton Sea), Oak Grove Ranger Station (southeast of Aguanga), Ocotillo Wells, Pala, Palm Springs, Palomar Mountain, Pine Valley, Plaster City, Poway, Rainbow Valley area (northeast of Fallbrook), Ranchita, Rancho Mirage, Redlands, Riverside (window cracked), Sage (south of Hemet), San Bernardino, San Diego, Santa Ana, Santa Ysabel, Santee, Temecula, Thousand Palms, Twenty-nine Palms, Valley Center, Westmorland, White Water, and Winchester. Intensity I to IV effects were noted at numerous towns in Arizona and California, and at Las Vegas, Nev.

April 29: 13:00 and 14:00. Several slight shocks were felt at the Descanso Ranger Station.

April 30: 08:45:25.0*. Epicenter $33^{\circ}17'$ north, $116^{\circ}14'$ west, southern California, P. Magnitude 3.6. Press reported this shock felt in the Borrego Springs area. Another was reported felt at 08:15.

May 5: 07:37:15.5*. Epicenter $33^{\circ}55'$ north, $118^{\circ}12'$ west, southern California, P. Magnitude 3.1. Intensity IV in Commerce area (east of Maywood), Glendale, Huntington Park-Watts area, and Maywood. Also felt about $2\frac{1}{2}$ miles east of Glendale at Eagle Rock.

May 5: 08:02:08.8*. Epicenter $34^{\circ}18'$ north, $117^{\circ}34'$ west, southern California, P. Magnitude 4.5. V. Felt over 2,000 square miles, principally in San Bernardino County, but no damage occurred. Intensity V at Phelan and Wrightwood. Intensity IV at Adelanto, El Mirage area (west of Adelanto), Etiwanda, Loma Linda, Lytle Creek, Pinon Hills, Rialto, Rimforest, Summit, Valyermo, and Victorville. Intensity I–III at Balboa, Crestline, Fawnskin, Fontana, Glendora, Lucerne Valley, and San Bernardino.

May 8: 14:10:53.1*. Epicenter $38^{\circ}42.2'$ north, $122^{\circ}10.3'$ west, northern California, B. Magnitude 4.0. Intensity IV at Brooks, Capay, and Guinda. Intensity I–III at Angwin.

May 9: 06:30:58.8*. Epicenter $33^{\circ}31'$ north, $118^{\circ}30'$ west, near coast of southern California, P. Magnitude 2.3. Felt at Long Beach.

May 12: 23:40:57.0*. Epicenter $40^{\circ}18'$ north, $124^{\circ}37'$ west, near coast of northern California, B. Magnitude 3.3. Intensity IV at Ferndale. Also felt at Petrolia.

May 19: 06:40:33.0*. Epicenter $33^{\circ}21.0'$ north, $116^{\circ}11.3'$ west, southern California, P. Magnitude 4.5. V. Felt over about 6,500 square miles of San Diego, Riverside, and Imperial Counties, but no damage was sustained. Intensity V at La Quinta, Ranchita, Salton City, Thermal, and White Water. Intensity IV at Borrego Springs, Campo, Cathedral City, Escondido, Hemet, Idyllwild, Lakeside, Mountain Center, Ocotillo Wells, Palm Desert, Palm Springs, Rancho Mirage, and Santa Ysabel (near). Intensity I–III at Boulevard, Coachella, Mount Laguna, Potrero, San Jacinto, Santa Ysabel, and Temecula. Press reported shock felt at La Jolla, Miramar, and the South Bay areas of San Diego.

May 23: 09:38:48.2*. Epicenter $37^{\circ}00.4'$ north, $121^{\circ}42.6'$ west, central California, about 7 miles west of Gilroy, near Corralitos, B. Magnitude 3.2. Intensity V at Corralitos, but no damage occurred. In-

tensity IV at Freedom. Also felt at Gilroy and Morgan Hill.

May 24: 04:41:45.0*. Epicenter $36^{\circ}59.6'$ north, $121^{\circ}41.0'$ west, central California, B. Magnitude 3.0. Intensity III north of Aptos. Also felt at Gilroy.

May 25: 14:31:28.4*. Epicenter $37^{\circ}51.9'$ north, $122^{\circ}01.8'$ west, central California, B. Magnitude 3.1. Intensity IV at Alamo and Oakland. Also felt at Walnut Creek.

May 29: 5:25 (a.m. or p.m. not given). Intensity III at Ferndale.

June 1: 21:38:55.2*. Epicenter $39^{\circ}21.4'$ north, $123^{\circ}14.7'$ west, northern California, in vicinity of Willits, B. Magnitude 3.1. Although no damage occurred, intensity V effects were noted at Potter Valley, Redwood Valley, and Willits (5 miles south of). Intensity IV at Lakeport, Navarro, Ukiah, Upper Lake, and Willits. Intensity I-III at Compche and Lake Mendocino (northeast of Ukiah).

June 5: 22:23:37.9*. Epicenter $34^{\circ}06'$ north, $117^{\circ}30'$ west, southern California, P. Magnitude 2.4. Intensity IV at Etiwanda.

June 7: 03:27:12.0*. Epicenter 40.8° north, 125.8° west, off coast of northern California, B. Magnitude 4.0. VI. At the Morrison Ranch, on Bear River about $3\frac{1}{2}$ miles east of Capetown, a chimney cracked and the top fell. Dishes broke. Knickknacks fell. Intensity V at Petrolia. Intensity IV at Ferndale.

June 7: 19:37:53.4*. Epicenter $34^{\circ}08'$ north, $117^{\circ}27'$ west, southern California, P. Magnitude 3.2. Intensity IV at Bloomington, Colton, East Highlands, Highland, Riverside, and San Bernardino. Intensity I-III at Etiwanda, Fontana, and Rialto.

June 8: 05:59:37.6*. Epicenter $33^{\circ}12.8'$ north, $115^{\circ}57.1'$ west, southern California, P. Magnitude 3.8. V. Windows broke at Salton City. Intensity IV at Coachella and North Shore. Intensity I-III at La Quinta.

June 8: 12:58. Sharp shock at Capetown (about $3\frac{1}{2}$ miles east of, at Morrison Ranch on Bear River).

June 9: 19:41:32.7*. Epicenter $31^{\circ}37.6'$ north, $116^{\circ}12.6'$ west, Baja California, P. Magnitude 5.0. Felt by some in San Diego.

June 10: 00:18:18.4*. Epicenter $35^{\circ}04'$ north, $116^{\circ}36'$ west, southern California, near Manix, P. Magnitude 3.7. Intensity III about 5 miles northwest of Helendale.

June 13: 14:19. Intensity IV at Petrolia.

June 14: 19:12. Intensity IV at Guadalupe.

June 18: 23:05:07.6*. Epicenter $36^{\circ}07'$ north, $119^{\circ}35'$ west, central California, B. Magnitude 3.5. Intensity IV at Corcoran, Dinuba, Hanford, Ivanhoe, Lemon Cove, Strathmore, and Tipton. Intensity I-III at Visalia.

June 18: 23:15. Intensity III at Ferndale.

June 22: 01:15:18.8* and 01:35:03.2*. Epicenters (1) $33^{\circ}55'$ north, $118^{\circ}43'$ west; (2) $33^{\circ}56'$ north, $118^{\circ}45'$ west, near coast of southern California, P. Magnitudes 3.6 and 2.8, respectively. Felt at Malibu.

June 27: 20:07:25.0*. Epicenter $40^{\circ}22'$ north, $124^{\circ}40'$ west, near coast of northern California, B. Magnitude 3.9. V. Felt over 2,500 square miles of Humboldt County, but no damage occurred. Intensity V at Alton, Eureka, Ferndale, Fortuna, Petrolia, Rio Dell, and Scotia. Intensity IV at Arcata, Bayside, Briceland (near), Bridgeville, Carlotta, Cuddeback, Fields Landing, Garberville, Grizzly Peak (north of), Korbelt, Loleta, Miranda, Rohnerville, Spruce Point (near Fields Landing), Trinidad, and Weott. Intensity I-III at Dinsmores (east of Bridgeville), Freshwater, Hyampom, Hydesville, Kneeland, McKinleyville, Phillipsville, Samoa, and Whitethorn.

July 1: 04:00:45.2*. Epicenter 40.3° north, 124.4° west, near coast of northern California, W. Magnitude 3.9, B. No damage occurred, but lamps, bottles, and other objects were knocked from shelves and tables. Intensity V at Elk River Road (5.2 miles south of Highway 101), Eureka, Ferndale, Petrolia, and Rio Dell. Intensity IV at Arcata, Bayside, Bridgeville, Carlotta,

Cutten, Fox Creek Road, Freshwater, Kneeland, Loleta, Redway, Samoa, Scotia, and Weott. Intensity I-III at Blue Lake, Hydesville, and Miranda.

July 8: 05:20:23*. Epicenter 40:4° north, 124.3° west, B. Magnitude 3.0. Intensity IV at Petrolia. Also felt at Carlotta and Ferndale.

July 15: 20:06:35*. Epicenter 35°50' north, 120°17' west, central California, B. Magnitude 3.4. V. Old cracks in concrete steps and garage floor opened slightly at William Alley Ranch, about 3.2 miles southeast of Cholame; small objects shifted at Creston and Parkfield (1 mile south of). Intensity IV at Cholame, Parkfield (6 miles southeast of), Paso Robles, and Shandon.

July 16: 19:03:33.7*. Epicenter 34°07.7' north, 117°46.3' west, southern California, P. Magnitude 3.2. Intensity III at Long Beach. Also felt at Claremont, Etiwanda, Laverne, and Pomona.

August 2: 12:13. Intensity IV in the Jenner area, 1 mile north of Timber Cove.

August 14: 11:04:07*. Epicenter 40.3° north, 124.2° west (poor location), B. Magnitude 3.1. Intensity III at Ferndale.

August 29: 09:42:18.1*. Epicenter 34°03.2' north, 117°17.5' west, southern California, P. Magnitude 3.0. Intensity III at San Bernardino.

August 30: 12:04:55*. Epicenter 37.6° north, 122.4° west, B. Magnitude 1.3. Intensity III at Pacifica.

September 6: 05:44:46.1*. Epicenter 35°14.8' north, 121°07.7' west, near coast of central California, P. Magnitude 3.7. Intensity IV at San Luis Obispo and San Simeon.

September 9: 12:14:40.6*. Epicenter 34°16.2' north, 116°45.9' west, southern California, P. Magnitude 3.4. Felt at Big Bear, Riverside, and San Bernardino.

October 1: 20:56:46.5*, 21:14:21.0*, 22:19:57.1*, 23:10:09.0*. Epicenters (1) 38°28.0' north, 122°41.5' west; (2) 38.5° north, 122.7° west; (3) 38°27.3' north, 122°41.5' west; (4) 38.5° north, 122.8° west, north-

ern California, Santa Rosa, B. Magnitudes 5.6, 3.5, 5.7, and 3.4, respectively. VII-VIII. The two main earthquakes, 20:56:46.5* and 22:19:57.1*, were felt over practically the same range of area, 10,500 square miles (see fig. 9). From a damage viewpoint the two earthquakes are considered as a single event. Virtually all of Santa Rosa's 50,000 population rushed to the streets when the first shock hit. Many spent the night outside, in parking lots or in city parks. A number of persons were left homeless due to the unsafe conditions of their houses.

Although a number of persons were injured by broken glass and falls, there were no fatalities. A survey of the Santa Rosa hospitals revealed 15 injuries and one probable heart attack as a result of the earthquakes. Total building damage was reported at \$6 million, and damage to dwelling contents at \$1,250,000.¹ Only slight damage occurred outside the Santa Rosa area. Large buildings were shaken in San Francisco, alarming some occupants. At the Pacific Gas and Electric Building on Market Street, two screws holding a metal floor plate between buildings were sheared off on the 10th floor.

INTENSITY VII-VIII:

Santa Rosa and vicinity.—A number of old brick and wood frame structures were damaged beyond repair and condemned. Chimneys fell. Numerous plate glass windows broke. Water mains, water pipes, and gaslines ruptured. Some sidewalks buckled. Minor ground cracking occurred. Swimming pools cracked. Tombstones overturned. There was heavy loss to medical equipment at the Memorial Hospital, much damage to store merchandise, and extensive damage to dwelling contents. On November 26, 1969, it was reported that in the commercial district, 21 buildings were damaged beyond repair and will be razed,

¹ *The Santa Rosa, California, Earthquakes of October 1, 1969*, Environmental Science Services Administration, National Earthquake Information Center, U.S. Government Printing Office, Washington, D. C., 1970.

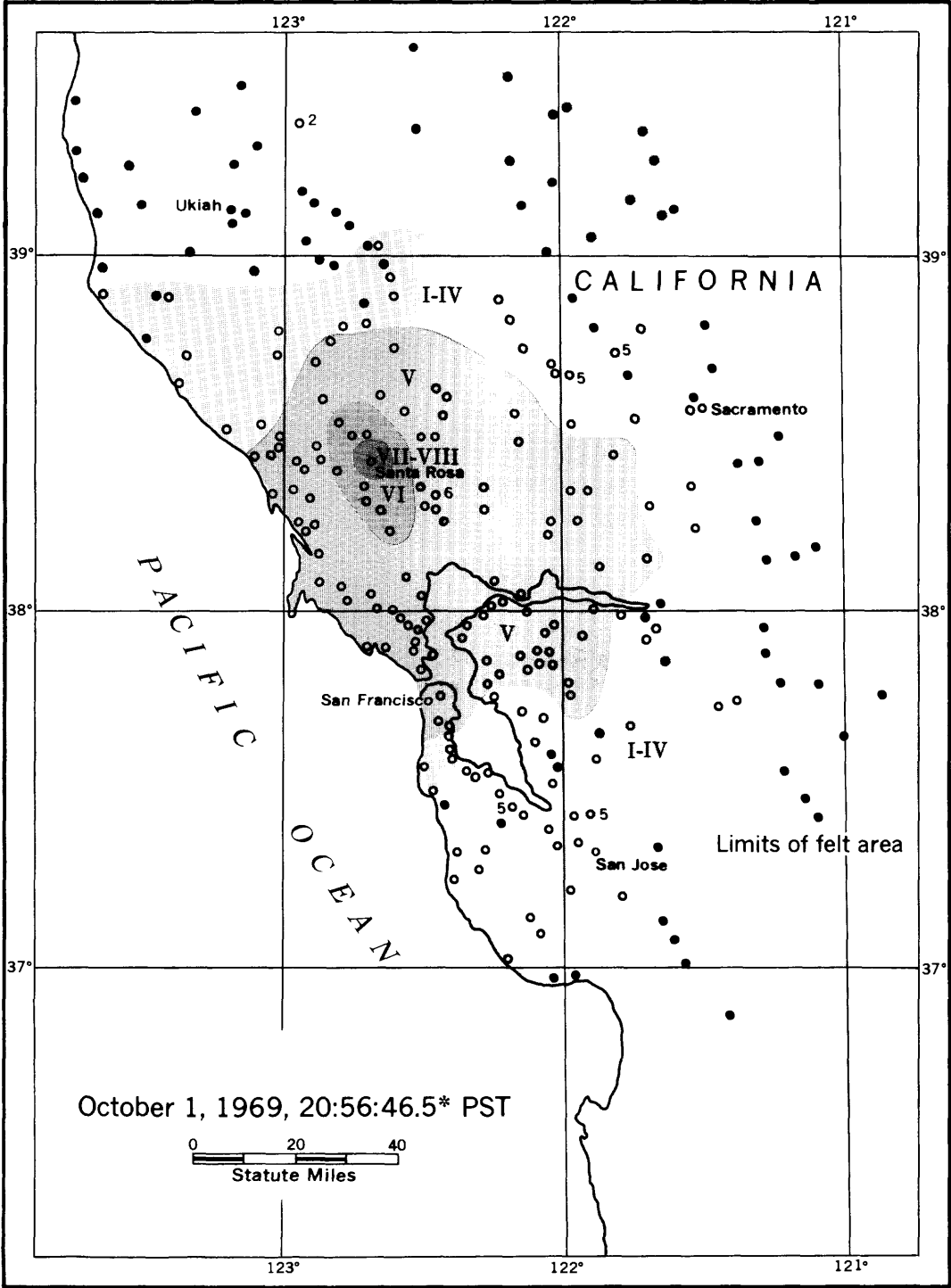


FIGURE 9.—Area affected by northern California earthquakes of October 1.

and 53 needed repair to meet lateral and/or vertical load requirements.

With the exception of the old Fremont Elementary School (condemned), only minor damage, in the form of fallen plaster, broken windows, and water pipe breakage, was reported at other Santa Rosa schools.

Serious damage occurred to the new Sonoma County Social Service Building, one of the buildings in the Sonoma County Administration complex. Practically every reinforced concrete column was cracked, and several exterior beams were cracked on the main floor of the two-story structure. Other buildings of the complex sustained only minor damage.

At J. C. Penney's, the newest major store in the Coddington Shopping Center, both structural and merchandise damage occurred. In addition, a 3-inch water main broke in the northeast corner of the second-floor ceiling, causing extensive water damage. The outer wall in the northeast corner of the building cracked, allowing small steel beams in the ceiling to pull loose and collapse the suspended ceiling. There was a crack one-half to three-fourths of an inch wide in the 10- to 12-inch-thick concrete of the second floor. Throughout the store the suspended acoustical ceiling was hanging, and some fell. Light fixtures fell in some areas of the building.

A large portion of brick fell from the exterior wall of the Miramar Tavern on Third Street at Courthouse Square. Three persons were hurt at the Roxie Theater when a part of the ceiling collapsed; a large crack was opened in the wall. Sections of the false ceiling fell at the new Ice Arena. The new Library and Post Office Buildings had substantial damage. Banks of fluorescent lights crashed to the floor in the post office. A California highway patrolman said the Library Building seemed to sway as much as 3 feet during the second major shock. The Pacific Telephone and Telegraph Company reported \$20,000 damage to its building. Two elevators in the build-

ing fell three stories. At the Santa Rosa Veterans Memorial Building, \$30,000 to \$40,000 damage was reported. There were cracks in the face of the lobby wall, broken pipes, and a hole in the roof caused by a rain downspout when it lanced through the 3-inch-thick concrete. At the State Farm Headquarters in Coddington, there was damage to ceiling tiles and light fixtures; two water mains broke. The ceiling and fireplace collapsed in an office building at 604 College Avenue. At 718 Beaver Street, an old two-story wooden house was badly twisted and otherwise damaged. A house at 520 Hearn Avenue was tilted off its foundation and moved about 1 foot to the east. A house twisted off its base at Wright Avenue near 14th Street. At 610 Beaver Street, a 100-year-old house was twisted on its foundation, with the north side bulging out about 1 foot; bricks fell. At the old Marshall House, 835 Second Street, a chimney toppled; bricks fell; plaster stripped from walls and ceilings; mouldings fell.

In downtown Santa Rosa, virtually every store from E Street west along Fourth Street to beyond the freeway had broken windows; some were also broken along Fifth Street. Twenty-one plate glass windows were broken at Rosenberg's Store. Ling's Furniture Store also suffered heavy window breakage. One glass company official said that from his survey, broken windows extended practically all over Santa Rosa. In many cases, metal frames holding the glass were also damaged.

There was a 3-inch shift at the north-bound on-ramp at the Highway 12 and Highway 101 intersection. A Division of Highways spokesman said the displacement was due to subsidence of the fill material where the looping third-deck bridge ends as it merges with the Highway 101 north-bound lanes. The lane remained open to traffic.

A Pacific Gas and Electric Company spokesman reported power outages were brief in most areas, but in some isolated

spots, power was off for several hours. Automatic equipment shut off the power when the first shock hit—a feature designed to minimize damage in case of fallen powerlines. Gas pipe leaks developed in many homes.

Press reported Kawana Springs (in an area about 2 miles southeast of Santa Rosa) was a flourishing resort until the 1906 earthquake “plugged up” its flowing waters. Now, the bottled-up springs are gushing again, as much as 1,000 gallons a day. Evidence of a freshly uncorked spring, one of seven on the property, was discovered when water was found in a normally dry creekbed. The shock also opened up springs in Mark West Creek north of Santa Rosa. The creek reportedly rose 8 inches after the earthquake.

In a report to the Seismological Field Survey, the superintendent of the Santa Rosa Water Department reported there were approximately 50 instances of water pipe damage. These include the breakage of 15 water mains, fire protection lines, and 30 service laterals to houses and buildings.

The following was extracted from a report by Robert D. Nason and Charles Bufe of ESSA's Earthquake Mechanism Laboratory, following a field investigation of the earthquake.

There were no reports of significant cracking or offset of roads anywhere, except for the settlement of some fill at a freeway overpass. The Rural Cemetery area near Poppy Drive, on the north side of Santa Rosa, was examined. Here, fresh fractures were found in the asphalt of Poppy Drive and cemetery roads immediately to the north. About 36 transverse fractures, 1/16 to 1/4 inch wide, were noted in Poppy Drive from 500 to 1,000 feet east of Franklin Avenue. These cracks involved perpendicular pull-apart of crack faces (perpendicular displacement vectors) with no apparent lateral-motion component. They did not form any sort of special en echelon or other pattern, so they were not directly due to strike-slip fault movement. The cracks occurred in a 500-foot-wide zone of fill ground and roadbed immediately north of a low pond and marsh, and not to either side of the marshy area. Thus, the cracks appear to be due to the heavy shaking of the marshy ground. The

loof (International Order of Odd Fellows) and Rural Cemeteries, south of Poppy Drive and west of the above-mentioned marsh pond, are on a small elongated hill or knoll about 10 to 40 feet higher than either side. In the two cemeteries, perhaps one-fifth of the pedestal-type monuments were thrown over, mostly to the west. Other pedestal-type monuments were rotated. As in the April 1968 earthquake, monument rotation in both clockwise and counterclockwise senses occurred, and in some cases, very near to each other. In at least one case in the Rural Cemetery, a monument that rotated clockwise in the April 1968 earthquake rotated counterclockwise in the October 1 earthquakes. In the central part of this cemetery, fresh, irregular cracks 1/8 to 1/4 inch wide occurred in the hard-packed, dry dirt roads. The cracks had irregular shapes and irregular trends, and were probably due to heavy seismic shaking at the site. This is the only known locality of soil fractures due to the October 1 earthquakes.

INTENSITY VI:

Cotati (1 mile southwest of).—Felt by all and awakened many in community. Trees and bushes shook. Small objects shifted, overturned, and fell. Damage slight (no details).

Fulton (1½ miles north of).—Felt by all in community; frightened all in home. Brick wall cracked. Shelved bricks fell off barbecue. Furniture shifted 2 inches. Observer also reported, “No damage found so far. I do not believe there was a vertical component, although sometimes a ‘dippy’ motion was felt. Mostly north-south swaying. At 22:19, swaying motion, lasting more than 30 seconds.”

Fulton (1 mile southwest of).—Felt by all and frightened many in community. Sudden jolt, with rolling and swaying motion. Trees and bushes shook; vehicles rocked. Hanging objects swung violently, mostly north-south. Dishes and glasses fell to floor. Furniture shifted.

Larkfield (about 5 miles north of Santa Rosa).—(Press) At the Larkfield Supermarket, much of the mess from the 20:56 shock had been cleaned up; then the 22:19 shock created another mess. At the nearby Larkfield Pharmacy, the owner said damage

was confined to a few bottles thrown off shelves.

Petaluma.—Felt by all, awakened many, and frightened few in community. Press noted one report of a cracked garage wall in a home east of the freeway and scattered reports of items being shaken from kitchen shelves, but the police and fire departments reported no calls of injuries or damage were received.

Rohnert Park (Sonoma State College, about 7 miles south of Santa Rosa).—(Press) College officials reported damage was limited to a broken window, fallen plaster, and other slight damage.

Sebastopol.—Felt by all in community; frightened few. Trees and bushes shook; vehicles rocked. Hanging objects swung violently north-south and east-west. Small objects shifted, overturned, and fell. Plaster cracked, broke, and fell. Damage slight.

Sonoma (4 miles north of).—Felt by, awakened, and frightened all in home. Plaster, chimney, pavement, and concrete fish pond cracked. Damage moderate.

Windsor.—Felt by all and frightened many in community. Waterlines broke. Hanging objects swung violently in all directions.

INTENSITY V:

Aetna Springs, Angwin, Annapolis, Benicia, Berkeley, Birds Landing, Bodega, Bodega Bay, Bolinas, Brisbane, Calistoga, Camp Meeker, Canyon, Clayton, Concord, Corte Madera, Crockett, Daly City, Danville, Dillon Beach, Dixon, Duncans Mills, Eldridge, Elmira, El Verano, Fairfax, Fallon, Forest Knolls, Forestville, Geyserville, Glen Ellen, Graton, Guerneville, Guerneville Park, Hamilton Air Force Base, Healdsburg, Hercules, Inverness, Jenner, Kellogg (about 20 miles northeast of Santa Rosa), Kentfield, Kenwood, Lafayette, Larkspur, Madison, Marshall, Martinez, Menlo Park, Middletown, Mill Valley, Milpitas, Monte Rio, Napa and 6 miles north of, Nicasio, Novato, Oakland, Oakville, Occidental, Olema, Orinda, Penn-

grove, Pescadero, Pinole, Pittsburg, Pleasanton, Point Reyes Station, Richmond, Rio Vista, Rodeo, Ross, Rutherford, Saint Helena and 4 miles west of, Saint Mary's College, San Anselmo, San Francisco, San Gregorio, San Pablo, San Quentin, San Rafael, San Ramon, Sausalito, Sonoma, Spanish Flat (about 25 miles northeast of Santa Rosa), Steele Park (about 25 miles east by north of Santa Rosa), Stinson Beach, Suisun City, The Geysers area (about 8 miles east of Cloverdale), Tiburon, Travis Air Force Base, Vacaville, Valley Ford, Veterans Home, Villa Grande, Vineburg, Walnut Creek, Woodacre, Yolo, and Youthville.

INTENSITY IV:

Alameda, Alamo, Alviso, Antioch, Boyes Hot Springs, Brentwood, Brooks, Burlingame, Capay, Cazadero, Clearlake Highlands, Cloverdale, Cobb, Cupertino, Davis, El Granada, Esparto, Fairfield, Fort Ross, Foster City, Guinda, La Honda, Livermore, Loma Mar, Los Gatos, Millbrae, Montara, Moraga, Mountain View, Mount Eden, Newark, Palo Alto, Pope Valley, Port Costa, Redwood City, Rheem Valley, San Bruno, San Carlos, San Geronimo, San Mateo, Santa Clara, South San Francisco, Stewarts Point, Tomales, Vallejo, and Winters.

INTENSITY I-III:

Asti, Banta, Castro Valley, Davenport, High Valley (4½ miles northwest of Clearlake Oaks), Knightsen, Knights Landing, Lake Berryessa area, Liberty Farms, Lower Lake, Merritt Island (about 4 miles south of Clarksburg), New Almaden, Piedmont, Point Arena, Rumsey, Sacramento, San Jose, San Leandro, Soda Creek Camp (about 10 miles northeast of Potter Valley), Sunol, Tracy, Walnut Grove, West Sacramento, and Zeni area (Gianoli Ranch, about 13 miles west of Yorkville).

October 2: 04:27:05.5*. Epicenter 38° 29.4' north, 122° 41.0' west, northern California, near Santa Rosa, B. Aftershock of October 1. Magnitude 4.3. Intensity V at Calistoga and Santa Rosa, but no damage

occurred. Intensity IV at Cazadero, Fort Ross, Fulton (near), Kenwood, and Tomales. Also felt at Concord, Duncans Mills, Forestville, Guinda, Healdsburg, Kellogg, Martinez, Orinda, San Francisco, Santa Rosa (5 miles northeast of), Sebastopol, and Windsor.

October 3: 05:10:11*. Epicenter 37.6° north, 118.8° west, California-Nevada border region, B. Magnitude 4.6. Intensity V at El Portal and Mono Hot Springs, but no damage was sustained. Intensity IV at Bridgeport, Catheys Valley, Control Gorge Power Plant (13 miles northwest of Bishop), Long Valley Dam (about 25 miles northwest of Bishop), Mammoth Lakes, Midpines, and Yosemite National Park. Intensity I-III at June Lake, Tom's Place (about 20 miles northwest of Bishop), and Wishon, and at Luning, Nev.

October 4: 22:54:54.4*. Epicenter 37° $52.8'$ north, $122^{\circ}02.2'$ west, central California, B. Magnitude 2.7. Intensity V at Isleton (no damage) and Rio Vista (slight wallboard cracks). Intensity IV at Birds Landing, Clayton, and Danville. Intensity I-III at Castro Valley, Oakland, and Walnut Creek.

October 6: 06:28:07*. Epicenter 38° $27.7'$ north, $122^{\circ}42.8'$ west, northern California, near Santa Rosa, B. Magnitude 3.9 Aftershock of October 1. Intensity IV at Calistoga and Santa Rosa. Also felt at Fulton, Healdsburg, and Kellogg.

October 6: 10:30. Aftershock of October 1. Intensity IV at Santa Rosa.

October 14: 05:18:39.9*. Epicenter 32.6° north, 116.5° west, California-Mexico border region, W. Magnitude 4.0, P. Widely felt in San Diego County, but no damage occurred. Intensity V at Alpine, Boulevard, Campo, Descanso, El Cajon, Jacumba (clay dislodged in spring), Julian, Mount Laguna, Pine Valley, San Diego, Santee, Valley Center, and Warner Springs. Intensity IV at Borrego Springs, Dulzura, La Jolla, Lakeside, Palomar Mountain, and Santa Ysabel. Intensity I-III at Escondido.

Press reported the shock was also felt at Imperial Beach, Mission Hills, and Pine Valley.

October 14: 17:28:53.6*. Epicenter 34° $19.9'$ north, $117^{\circ}35.3'$ west, P. Magnitude 3.5. Intensity IV at Pinon Hills. Intensity I-III at Etiwanda and Wrightwood.

October 17: 14:55:15.7*. Epicenter 40.3° north, 124.2° west, near coast of northern California, W. Magnitude 4.5. Intensity I-III at Ferndale.

October 22: 14:02:43.1*. Epicenter 40.4° north, 123.8° west, northern California, W. Magnitude 4.4. Intensity V at Fruitland (11 miles south of Weott). Intensity IV at Bridgeville and Weott. Intensity I-III at Ferndale.

October 22: 14:51:29.0*. Epicenter 34° $34.6'$ north, $121^{\circ}37.2'$ west, off coast of California, B. Magnitude 5.4. P. Felt in scattered localities of coastal areas from Paso Robles (San Luis Obispo County) to Pacific Palisades (Los Angeles County). V. Objects knocked off shelves at Lompoc. Plaster cracked at Pismo Beach. Slight damage at San Luis Obispo (no details). Violent jolt at Surf; pendulum clock stopped. Frightened all at Vandenberg Air Force Base (about 10 miles northwest of Lompoc); small objects and furniture shifted. Intensity V effects also noted at Arroyo Grande, Betteravia, and Guadalupe. Intensity IV at Casmalia, Los Alamos, Nipomo, Pacific Palisades, and Santa Maria. Intensity I-III at Paso Robles and Santa Barbara.

October 24: 00:29:12.1*. Epicenter $33^{\circ}17.5'$ north, $119^{\circ}11.6'$ west, off coast of southern California, P. Magnitude 5.1. V. Felt principally in the coastal areas of Los Angeles, Orange, and Ventura Counties. Very slight plaster cracking at Downey. Intensity V also reported at Long Beach, Los Angeles, Malibu, Maywood, Newport Beach (damage slight; no details), Oxnard, Sunset Beach, Torrance, Westminster, and Wilmington. Intensity IV at Canoga Park,

Compton, Harbor City, Hawthorne, Northridge, Pasadena, Redondo Beach, Stanton, and Ventura. Intensity I-III at Azusa, Garden Grove, San Pedro, and Santa Barbara.

October 24: 04:17. Felt at Newport Beach.

October 24: 12:26:42.5*. Epicenter $33^{\circ} 20.3'$ north, $119^{\circ} 06.3'$ west, off coast of southern California, P. Magnitude 4.7. Press reported the shock was felt at Long Beach, Redondo Beach, and in downtown Los Angeles. A press report of October 27 stated: "In the cliff area on coast south of San Pedro, along Paseo Del Mar, a 200-foot-long fissure split one home in two, slowly cut through another, and knocked two other homes off their foundations. The houses are located 200 feet above the beach." The crack, described as 2 feet wide and nearly 100 feet deep, was believed to have been triggered by two earthquakes in southern California "last week."

October 27: 02:59:42.8*. Epicenter $36^{\circ} 47.4'$ north, $121^{\circ} 23.6'$ west, central California, B. Magnitude 4.6. VI. Felt over approximately 4,000 square miles. Slight damage occurred at one place in Hollister, where plaster cracked and a wall joint opened slightly at an old school building. In a report of the field investigation conducted by personnel from the California Division of Mines and Geology and the ESSA Earthquake Mechanism Laboratory, it was stated that no evidence was found of increased lateral offset on either the Calaveras or San Andreas Fault zones, nor was there any significant offset on creep-meter crossing the San Andreas Fault at the Almaden Winery (about 9 miles south of Hollister). No landslides or rockfalls were observed which definitely could be attributed to the earthquake.

INTENSITY VI:

Hollister.—Felt by and awakened all in community. Field investigators reported: Structural damage occurred in one building of the San Benito County High School.

A wedge-shaped opening developed at a vertical wall joint—closed at bottom and opened $\frac{1}{2}$ to 1 inch at top. This joint marked the boundary between the original outside wall and a later addition to the structure. Many fresh cracks developed in the ceiling plaster near the walls in several rooms of the original structure (built in 1916). Described as a sharp jolt, lasting several seconds. A market at south end of town lost several bottles of liquor and food items; some cans were toppled at a gas station near the market; some items fell from shelves at a ranch 3 miles south of town. Described generally as the strongest shock since April 1961. Hollister postmaster reported glass on post office scale broke and that loud, rumbling earth noises were heard before shock.

INTENSITY V:

Carmel Valley, Chualar, Cienega District (south of Hollister; 7391 Cienega Road; Harris Ranch, 7800 Cienega Road; Almaden Winery, 9970 Cienega Road; 12830 Cienega Road; 13150 Cienega Road; Libby Ranch, 1313 Limekiln Road), Gonzales, Mee Ranch (intersection of Highway 198 and 25; plaster cracked), Paicines, Panoche, Pinnacles National Monument, Salinas, San Juan Bautista, Soledad, Soquel, Spreckels, and Tres Pinos.

INTENSITY IV:

Bear Valley (Sec.3, T.16S, R.7E), Big Sur, Carmel, Felton, Freedom, Greenfield, Marina, Monterey, Moss Landing, and Robles del Rio (Carmel Valley).

INTENSITY I-III:

Aptos (3.6 miles north of), Capitola, Gilroy, San Francisco, and Seaside.

October 27: 05:16:02.3*. Epicenter $33^{\circ} 32.7'$ north, $117^{\circ} 48.4'$ west, southern California, near Laguna Beach, P. Magnitude 4.5. V. Felt over approximately 4,500 square miles, principally in Orange, Riverside, and San Bernardino Counties. Few small plaster cracks reported at Huntington Beach. Intensity V also reported at Artesia, Bloomington, Buena Park, Capistrano

Beach, Costa Mesa, Dana Point (about 6 miles south of Laguna Beach), East Irvine, El Toro, Escondido, Fallbrook, Garden Grove, Hemet, Huntington Park, Laguna Beach, Lomita, Los Alamitos, Murrieta, Newport Beach, Perris, Riverside, San Bernardino, San Juan Capistrano, Santa Ana, Silverado, South Laguna, Sunset Beach, Surfside, Temecula, Trabuco Canyon, Tustin, and Wildomar. Intensity IV at Aguanga, Bellflower, Bonsall, Brea, Compton, Corona del Mar, Elsinore, Fullerton, Hawthorne, La Mirada, Lawndale, Long Beach, Midway City, North Hollywood, Ontario, Orange, Pomona, San Clemente, San Dimas, San Luis Rey, Stanton, Valley Center, Westminster and Winchester. Intensity I-III at El Monte, Etiwanda, Harbor City, La Habra, Malibu, San Gabriel, San Jacinto, and Yorba Linda.

October 31: 01:12:13.6*. Epicenter $34^{\circ}38.6'$ north, $121^{\circ}28.9'$ west, off coast of California, P. Magnitude 3.8. Pismo Beach and coastal area shaken.

October 31: 02:39:29.0*. Epicenter $33^{\circ}25.8'$ north, $119^{\circ}05.8'$ west, off coast of California, near Santa Barbara Island, P. Magnitude 4.8. Press reported the shock was felt in widely scattered areas of Los Angeles. Windows and walls rattled in the Civic Center.

November 5: 09:54:07.9*. Epicenter $34^{\circ}36.5'$ north, $121^{\circ}26.1'$ west, off coast of California, B. Magnitude 5.6. V. Felt over a considerable area of San Luis Obispo and Santa Barbara Counties. Minor plaster cracking reported at Avila Beach. Intensity V also reported at Arroyo Grande, Casmalia, Guadalupe, Harmony, Lompoc, Morro Bay, Oceano, Pismo Beach, San Luis Obispo, Templeton, and Vandenberg Air Force Base. Intensity IV at Goleta, Los Alamos, Los Olivos, Los Osos, Nipomo, San Simeon, Santa Margarita, and Santa Maria. Intensity I-III at Atascadero, Cambria, Carpinteria, Cayucos, Santa Barbara (University of California), and Santa Ynez.

November 5: 10:48:43.1*. Epicenter 34°

$44.6'$ north, $121^{\circ}26.7'$ west, off coast of California, B. Magnitude 4.5. Felt in Lompoc area.

November 15: 12:58:03.6*. Epicenter $36^{\circ}44.7'$ north, $121^{\circ}24.4'$ west, central California, B. Magnitude 4.2. V. Felt by all and frightened few at Paicines. Several cans fell from shelves in grocery store. At the Libby Ranch (about $2\frac{1}{2}$ miles southwest of Paicines in Cienega Valley), felt by all. One sharp jolt. Plaster cracked slightly. Intensity IV at Castroville, Chualar, Cienega District (Harris Ranch, 7800 Cienega Road; Almaden Winery, 9970 Cienega Road; Mills Ranch, 7391 Cienega Road; 12500 Cienega Road; 13150 Cienega Road; 12830 Cienega Road), Gonzales, San Juan Bautista, Soledad, and Spreckels. Intensity I-III at Hollister, Marina, Pacific Grove, and Salinas.

November 17: 12:49:19.5*. Epicenter $36^{\circ}25.6'$ north, $121^{\circ}00.3'$ west, central California, B. Magnitude 4.3. V. Felt over approximately 4,000 square miles. Sidewalk cracked at Pine Canyon. Intensity V effects at Bar B Ranch (about 10 miles southwest of Idria), Carmel Valley, and Idria. Intensity IV at Big Sur, Chualar, Cienega District (south of Hollister; 7391 Cienega Road; Harris Ranch, 7800 Cienega Road; 12500 Cienega Road; 12830 Cienega Road; 13150 Cienega Road; Libby Ranch), Gonzales, Greenfield, Hernandez (2 miles northwest of), King City, Mee Ranch (intersection of Highway 198 and 25, east of King City), Paicines, San Juan Bautista, Seaside, Slack Canyon, Soledad, and Spreckels. Intensity I-III at Capitola, Marina, Monterey, Salinas, and San Lucas.

November 18: 22:28:48.0*. Epicenter 36.4° north, 121.6° west, central California, W. Magnitude 4.2, B. V. Felt over approximately 3,500 square miles, but no damage was reported. Intensity V effects at Carmel Valley, Chualar, Gonzales, Pine Canyon (about 8 miles southwest of King City), and Seaside. Intensity IV at Aptos (3.6 miles north of), Arroyo Seco (about

15 miles southwest of Soledad), Big Sur, Capitola, Carmel, Castroville, Cienega District (south of Hollister; 13150 Cienega Road; Libby Ranch), Greenfield, Hollister, Marina, Monterey, Pacific Grove, Prunedale, Salinas, Soledad, and Spreckels. Intensity I-III at Harris Ranch (7 miles south of Hollister in Cienega District) and Lonoak (about 15 miles northeast of King City).

November 21: 01:30 and 06:50. Intensity **IV** at Santa Rosa.

November 24: 22:32. Intensity **III** at Bridgeville.

December 2: 02:49:14.5*. Epicenter $33^{\circ}58.8'$ north, $118^{\circ}19.6'$ west, P. Magnitude 3.1. Press reported a moderate earthquake shook Hollywood and Los Angeles. Woman in central downtown Los Angeles area jumped up from bed when the large building seemed to move.

December 10: 05:25:31*. Epicenter $35^{\circ}46'$ north, $120^{\circ}24'$ west, central California, B. Magnitude 3.5. Intensity **V** at Parkfield and Work Ranch (15 miles northeast of San Miguel; some plaster fell). Intensity **IV** at Coalinga. Intensity I-III at Priest Valley and Shandon.

December 14: 03:01:45.6*. Epicenter 40.4° north, 123.7° west, northern California, W. Magnitude 4.2. Intensity **IV** at Rio Dell.

December 19: 05:10 (about). Intensity **IV** at Ferndale and Rio Dell.

December 21: 19:03:26.5*. Epicenter $37^{\circ}51.6'$ north, $121^{\circ}56.6'$ west, central California, B. Magnitude 3.3. Felt at Dublin, San Ramon, and Walnut Creek. Well cracked 200 feet below surface at Dublin.

December 25: 11:43:52.6*. Epicenter $36^{\circ}47.2'$ north, $121^{\circ}17.3'$ west, central California, B. Magnitude 2.9. Intensity **IV** near Hollister.

December 29: 11:31:11.4*. Epicenter $37^{\circ}46.0'$ north, $121^{\circ}42.5'$ west, central California, B. Magnitude 3.8. Intensity **I-III** at Livermore and Tracy; also felt at Byron.

WASHINGTON AND OREGON

[120th Meridian or Pacific Standard Time]

February 14: 00:33:37.5*. Epicenter $48^{\circ}43.7'$ north, $123^{\circ}05.9'$ west, eastern Saturna Island, Vancouver Island region, British Columbia, S. Magnitude 4.5. **V**. In the United States, the shock was felt over 5,000 square miles of northwestern Washington, but no damage was noted. In British Columbia, press reports indicated the shock was felt at Abbotsford, Vancouver, Victoria, and in the Fraser River Valley. Intensity **V** at Acme, Bellingham, Blaine, Deer Harbor, Eastsound, Edison, Ferndale, Freeland, Friday Harbor, Index, Joyce, Lakewood, Lopez, Lummi Island, Lynden, Maple Falls, Nooksack, Olga, Orcas, Point Roberts, Roche Harbor, and Waldron. Intensity **IV** at Blanchard, Carlsborg, Clallam Bay, Clinton, Concrete, Conway, Coupeville, Custer, Darrington, Deming, Everson, Indianola, La Conner, Lake Stevens, Lyman, Marietta, Marysville, Neah Bay, Nordland, Port Angeles, Port Gamble, Port Townsend, Quilcene, Rockport, Seabeck, Shaw Island, and Sumas. Intensity I-III at Anacortes, Bow, Greenbank, Hamilton, Hansville, Mukilteo, Olympia, Seattle, Stanwood, and Sultan.

March 5: 03:44. Magnitude 3.5. Recorded at Baker, Oreg. (Blue Mountains Seismological Observatory). Intensity **IV** at Vancouver, Wash.

August 13: 08:04:41.4* and 10:53:48.8*. Epicenter 48.5° north, 122.5° west, northwestern Washington, near Anacortes, S. Magnitudes 2.0 and 2.5, respectively. Intensity **III** at Anacortes and La Conner.

August 14: 06:37:39.8*. Epicenter 45.0° north, 117.7° west, eastern Oregon, W. Felt at Haines and North Powder.

August 19: 07:42:49.1*. Epicenter 48.5° north, 122.5° west, northwestern Washington, near Anacortes, W. Magnitude 2.5. Intensity **III** at Anacortes and La Conner.

October 9: 09:07:55.0*. Epicenter $46^{\circ}46'$ north, $121^{\circ}43'$ west, Washington, S.

Magnitude 4.0. V. Felt over 2,000 square miles of Lewis and Pierce Counties. Intensity V (no damage) at Elbe and Packwood. Intensity IV at Carbonado, Glenoma, Morton, Randle, and Winlock. Intensity I-III at Ashford, La Grande, and Wilkeson.

November 1: 07:44:24.3*. Epicenter 47°55' north, 121°51' west, Washington, S. Magnitude 4.0. V. Felt over approximately 7,000 square miles of northwestern Washington, but no damage was reported. Intensity V effects at Baring, Duvall, Edmonds, Gold Bar, Grotto, Index, Lake Stevens, Skykomish, Startup, and Sultan. Intensity IV at Arlington, Belfair, Bush Point (west of Langley), Carnation, Conway, Darrington, Dockton, Fall City, Granite Falls, Issaquah, Kenmore, Marblemount, Marysville, Monroe, North Bend, Pacific, Preston, Redmond, Seattle, Silvana, Snohomish, Stanwood, and Woodinville. Intensity I-III at Bellevue, Clinton, Edison, Elbe, Everett, Hobart, Kent, Lakewood, Lyman, Port Gamble, Rockport, and Silverdale.

November 9: 23:38:40.8*. Epicenter 48°31' north, 121°24' west, northwestern Washington, S. Magnitude 4.7. V. Probable felt area on order of 7,000 square miles, but no definite damage was reported. Intensity V effects at Concrete (5 miles west of), Marblemount (damage slight; no details), and Rockport. Intensity IV at Acme, Bellingham (12 miles east of, on Mt. Baker Highway), Blanchard, Brewster, Darrington, Gold Bar, Grotto, Hamilton, Index, Lyman, Mount Vernon, Preston, and Sumas. Intensity I-III at Clearlake, Freeland, Hobart, Lakewood, Omak, and Riverside.

November 28: 01:51:32.9*. Epicenter 47.4° north, 122.7° west, northwestern Washington, S. Magnitude 3.5. Intensity IV at Bremerton, Burley, Manchester, Port Orchard, and Poulsbo.

ALASKA

[150th Meridian or Alaska Standard Time]

January 3: 01:38:03.4*. Epicenter 61.0° north, 151.0° west, southern Alaska, W. Felt at Anchorage.

January 3: 03:28:12.8*. Epicenter 51.2° north, 179.4° west, Andreanof Islands, W. Magnitude 5.2. Felt on Adak.

January 5: 11:21:05.0*. Epicenter 64.8° north, 147.4° west, central Alaska, W. Felt in Fairbanks area.

February 5: 13:07:15.2*. Epicenter 64.8° north, 147.2° west, central Alaska, W. Felt at Fairbanks.

February 5: 23:33:46.5*. Epicenter 51.6° north, 176.2° west, Andreanof Islands, W. Magnitude 5.0. V. Extensive glassware breakage on Adak; mirrors broke; plaster cracked. Majority of population confined to a 10 square-mile area on Adak.

February 14: 22:34:55.6*. Intensity III at Cape Yakataga.

March 8: 16:46:09.2*. Epicenter 64.8° north, 147.7° west, central Alaska, W. Felt at Fairbanks.

March 3: 16:24:56.2*. Epicenter 60.0° north, 152.7° west, southern Alaska, W. Felt at Anchorage.

March 14: 08:28:12.9*. Epicenter 65.4° north, 150.1° west, central Alaska, W. Magnitude 4.4. Felt at Fairbanks.

March 15: 03:35:35.3*. Epicenter 51.2° north, 179.1° west, Andreanof Islands, W. Magnitude 5.2. Felt on Adak.

March 20: 23:46:28.3*. Epicenter 59.9° north, 152.7° west, southern Alaska, W. Magnitude 4.5. Felt in Anchorage-Palmer area.

March 31: 13:00:08.0*. Epicenter 51.9° north, 178.0° west, Andreanof Islands, W. Magnitude 4.5. Felt on Adak.

April 1: 11:33:10.0*. Epicenter 55.8° north, 161.3° west, Alaska Peninsula, W. Magnitude 4.6. Intensity III at King Cove.

April 8: 20:49:03.9*. Epicenter 67.1° north, 162.3° west, Alaska, W. Magnitude

4.2. Intensity **III** at White Alice Communications Site near Kotzebue.

April 9: 12:34:43.3*. Epicenter 64.8° north, 147.5° west, central Alaska, W. Intensity **IV** at College. Also felt at Chena Hot Springs.

April 9: 16:04:07.6*. Felt on Adak.

April 15: 00:02:35.4*. Epicenter 64.8° north, 147.4° west, central Alaska, W. Felt at Fairbanks.

April 19: 09:26:17.3*. Epicenter 60.3° north, 146.0° west, southern Alaska, W. Magnitude 5.1. Felt at Cordova.

April 22: 00:10:36.3*. Epicenter 57.0° north, 154.0° west, Kodiak Island region, W. Magnitude 3.7. Intensity **IV** at the U.S. Coast Guard LORAN Station on Sitkinak Island.

May 14: 00:26:51.3*. Epicenter 61.2° north, 149.8° west, southern Alaska, W. Magnitude 3.9. Felt at Anchorage.

May 14: 09:32:54.2*. Epicenter 51.3° north, 179.9° west, Andreanof Islands, W. Magnitude 7.0. **V**. Plaster cracked on Adak and Amchitka Islands. "It was necessary to brace oneself to keep from falling. Was very evident that building and furniture were moving from side to side. Only damage was to small knickknacks on shelves."

May 14: 10:10:39.3*. Epicenter 51.3° north, 179.9° west, Andreanof Islands, W. Magnitude 5.3. Felt on Adak.

May 14: 12:46:31.0*. Epicenter 51.5° north, 179.7° west, Andreanof Islands, W. Magnitude 4.6. Felt on Adak.

May 17: 22:44:03.6*. Epicenter 60.3° north, 146.0° west, southern Alaska, W. Magnitude 5.4. Intensity **V** at Cordova (no damage). Also felt in Hill Building at Anchorage (**III**).

May 23: 05:44:51.6*. Epicenter 51.4° north, 176.6° west, Andreanof Islands, W. Magnitude 4.4. Felt on Adak.

May 27: 20:48:14.3*. Epicenter 60.3° north, 145.8° west, southern Alaska, W. Magnitude 3.3. Felt at Cordova.

June 6: 08:05:30.0*. Epicenter 64.9°

north, 147.5° west, central Alaska, W. Felt at College and Fairbanks.

June 8: 22:02:17.2*. Epicenter 62.4° north, 149.0° west, central Alaska, W. Magnitude 4.1. Felt at Palmer.

June 10: 14:58:10.1* and 15:05:01.3*. Epicenter 59.6° north, 144.8° west, Gulf of Alaska, W. Magnitudes 5.3 and 4.9, respectively. Felt at Cordova.

June 17: 15:38:46.4*. Epicenter 59.5° north, 145.0° west, Gulf of Alaska, W. Magnitude 5.2. Felt sharply at Cordova.

June 19: 10:24:59.6*. Epicenter 54.2° north, 164.0° west, Unimak Island region, W. Magnitude 5.0. Intensity **III** at Cold Bay.

June 20: 22:41:21.1*. Epicenter 65.2° north, 147.8° west, Alaska, W. Magnitude 4.1. Intensity **IV** at Fairbanks.

June 22: 00:45:24.5*. Epicenter 51.5° north, 179.9° west, Andreanof Islands, W. Magnitude 6.1. Felt on Adak and Amchitka.

June 22: 05:58:17.9*. Epicenter 51.6° north, 180.0° west, Andreanof Islands, W. Magnitude 4.9. Felt on Amchitka.

July 3: 08:01:48.5*. Epicenter 51.7° north, 178.0° east, Rat Islands, W. Magnitude 5.1. Felt on Amchitka.

July 17: 10:51:37.5*. Epicenter 64.1° north, 147.6° west, central Alaska, W. Magnitude 4.9. Felt at Fairbanks and with intensity **IV** at Gilmore Creek.

July 17: 10:55:04.3*. Epicenter 64.0° north, 147.3° west, central Alaska, W. Magnitude 4.5. Felt at Fairbanks and Gilmore Creek.

July 17: 12:03:36.7*. Epicenter 64.0° north, 147.5° west, central Alaska, W. Magnitude 4.2. Felt at Fairbanks and Nenana.

July 31: 02:06:44.5*. Epicenter 64.9° north, 151.2° west, central Alaska, W. Magnitude 4.4. Intensity **IV** at Tanana.

July 31: 22:17. Intensity **IV** at Cold Bay.

August 4: 00:23:28.9*. Epicenter 51.4° north, 179.6° west, Andreanof Islands, W. Magnitude 5.3. Felt on Amchitka.

August 5: 14:38:42.8*. Epicenter 61.4° north, 150.7° west, southern Alaska, W.

Magnitude 4.8. Intensity **IV** at Anchorage and Talkeetna (FAA Station). Also felt at Kenai and Palmer.

August 25: 10:07:57.7*. Epicenter 65.1° north, 147.4° west, Alaska, W. Magnitude 4.0. Intensity **IV** at College. Also felt at Fairbanks.

August 26: 18:53:13.6*. Epicenter 60.1° north, 153.0° west, southern Alaska, W. Magnitude 4.5. Felt at Homer.

September 11: 21:15:50.0*. Epicenter 51.3° north, 179.2° west, Andreanof Islands, W. Magnitude 5.0. Felt on Amchitka.

September 11: 22:57:07.3*. Epicenter 51.2° north, 179.2° west, Andreanof Islands, W. Magnitude 6.6. Felt on Adak and Amchitka.

September 15: 04:45:42.0*. Epicenter 51.9° north, 175.5° east, Rat Islands, W. Magnitude 5.2. Intensity **III** on Shemya.

September 18: 21:00. Intensity **IV** at Bettles Field.

September 26: 01:25:17.6*. Epicenter 60.1° north, 153.0° west, southern Alaska, W. Magnitude 4.7. Intensity **III** at Diamond Ridge.

September 29: 11:37:36.4*. Epicenter 51.7° north, 177.1° west, Andreanof Islands, W. Magnitude 4.4. Felt on Adak.

October 3: 22:26:53.9*. Epicenter 62.2° north, 149.8° west, central Alaska, W. Magnitude 3.7. Felt at Anchorage and Talkeetna.

October 9: 23:36:09.8*. Epicenter 64.8° north, 147.2° west, central Alaska, W. Magnitude 3.9. Felt at Fairbanks.

October 10: 00:20:46.5*. Epicenter 64.7° north, 147.2° west, central Alaska, W. Magnitude 4.0. Felt at Fairbanks.

October 10: 08:56:30.5*. Epicenter 60.5° north, 148.7° west, Kenai Peninsula, W. Magnitude 3.8. Felt at Whittier.

October 16: 11:00:46.5*. Epicenter 62.5° north, 151.3° west, central Alaska, W. Magnitude 4.0. Felt in Anchorage-Talkeetna area.

October 17: 22:44:00.0*. Epicenter 52.5° north, 173.5° east, Near Islands, W. Magnitude 5.3. Intensity **IV** on Shemya.

October 31: 01:33:04.8*. Epicenter 51.3° north, 179.0° west, Andreanof Islands, W. Magnitude 6.3. Intensity **IV** on Adak.

November 6: 10:20:18.5*. Epicenter 51.5° north, 178.9° west, Andreanof Islands, W. Magnitude 5.7. Felt on Adak and Amchitka.

November 6: 15:52:35.7*. Epicenter 62.0° north, 150.3° west, central Alaska, W. Magnitude 3.8. Intensity **IV** at Willow.

November 15: 21:51:11.0*. Epicenter 64.1° north, 147.5° west, central Alaska, W. Magnitude 4.4. Intensity **IV** in College-Fairbanks area, Delta Junction, and Nenana.

November 16: 09:57:40.3*. Epicenter 64.1° north, 147.5° west, central Alaska, W. Magnitude 4.4. Intensity **IV** in College-Fairbanks area; felt slightly at Nenana.

November 20: 13:46:11.6*. Epicenter 56.6° north, 153.2° west, Kodiak Island region, W. Magnitude 5.5. Intensity **IV** on Sitkinak Island.

November 20: 14:29:50.1*. Epicenter 56.4° north, 153.6° west, Kodiak Island region, W. Magnitude 5.2. Intensity **IV** on Sitkinak Island.

November 23: 00:30. (Not recorded at College Observatory). Intensity **IV** at Cold Bay.

November 23: 23:42. (Not recorded at College Observatory). Intensity **V** at Cold Bay and King Cove. No damage reported.

November 24: 12:51:50.1*. Epicenter 56.2° north, 153.6° west, Kodiak Island region, W. Magnitude 5.7. Intensity **IV** on Sitkinak Island.

December 25: 16:30. (Not recorded at College Observatory). Intensity **V** at King Cove. No damage reported.

December 28: 23:30. (Not recorded at College Observatory). Intensity **IV** at King Cove.

HAWAII

[150th Meridian or Hawaiian Standard Time]

NOTE: Data on the following local disturbances were determined from seismograph stations on the Islands of Hawaii and Maui by the Hawaiian Volcano Observatory of the U.S. Geological Survey.

January 5: 17:25:00.2*. Epicenter 19° 19.8' north, 155°13.2' west, at a depth of 10 km. Magnitude 3.6. Felt at Kilauea.

January 5: 18:31:26.7*. Epicenter 19° 18.8' north, 155°13.3' west, at a depth of 10 km. Magnitude 3.0. Felt at Kilauea.

January 14: 21:37:06.0*. Epicenter 19° 47.7' north, 155°30.9' west, at a depth of 8 km. Magnitude 3.8. Felt at Hilo, Kamuela, Kealakekua, and Pepeekeo.

January 20: 05:55:26.0*. Epicenter 19° 22.3' north, 155°29.9' west, at a depth of 8 km. Magnitude 3.2. Felt at Pahala.

January 28: 07:34:37.1*. Epicenter 19° 24.0' north, 155°24.9' west, at a depth of 8 km. Magnitude 3.2. Felt at Hilo and Pahala.

February 6: 23:33:51.1*. Epicenter 19° 12.3' north, 155°21.2' west, at a depth of 45 km. Magnitude 3.5. Felt at Kealakekua and Pahala.

February 7: 05:59:36.6*. Epicenter 19° 21.3' north, 155°23.1' west, at a depth of 30 km. Magnitude 3.5. Felt at Kealakekua, Kilauea, Mountain View, and Pahala.

February 8: 22:56:43.8*. Epicenter 19° 20.3' north, 155°09.0' west, at a depth of 10 km. Magnitude 3.3. Felt at Hilo.

February 9: 16:24:42.2*. Epicenter 19° 20.2' north, 155°08.1' west, at a depth of 10 km. Magnitude 4.1. Felt at Hilo, Honokaa, Kamuela, Kealakekua, Kilauea, Mountain View, and Pohakuloa.

February 17: 00:42:00.6*. Epicenter 19° 18.7' north, 155°13.1' west, at a depth of 10 km. Magnitude 3.3. Felt at Hilo, Kilauea, Pahala, and Pohakuloa.

February 28: 07:33:35.0*. Epicenter 19° 18.8' north, 155°24.7' west, at a depth of 32 km. Magnitude 3.7. Felt at Hilo, Kealakekua, Mountain View, and Pahala.

February 28: 17:40:41.9*. Epicenter 19° 25.5' north, 155°26.2' west, at a depth of 8 km. Magnitude 3.7. Felt at Hilo and Pahala.

March 4: 18:16:10.3*. Epicenter 18° 59.5' north, 155°29.3' west, at a depth of 35 km. Magnitude 3.6. Felt at Pahala.

March 11: 03:35:07.6*. Epicenter 19° 23.5' north, 155°16.9' west, at a depth of 27 km. Magnitude 3.5. Felt at Kilauea, Naalehu, Pahala, and Pohakuloa.

March 11: 10:10:13.2*. Epicenter 19° 13.2' north, 155°27.9' west, at a depth of 8 km. Magnitude 3.7. Felt at Kealakekua, Kilauea, and Pahala.

April 9: 07:30:56.1*. Epicenter 20° 59' north, 155°43' west, at a depth of 13 km. Magnitude 4.2. Felt at Hana, Maui.

April 18: 21:25:57.0*. Epicenter 19° 26.0' north, 155°26.7' west, at a depth of 8 km. Magnitude 3.4. Felt at Kilauea and Pahala.

April 28: 04:48:25.1*. Epicenter 19° 24.8' north, 155°27.4' west, at a depth of 9 km. Magnitude 3.2. Felt at Kealakekua, Kilauea, Pahala, and Pohakuloa.

May 5: 01:05:03.8*. Epicenter 19°29.3' north, 155°37.9' west, at a depth of 8 km. Magnitude 3.7. Felt Island-wide.

May 7: 04:35:59.0*. Epicenter 20°50' north, 155°21' west, at a depth of 13 km. Magnitude 4.5. Felt at Hana (Maui), Kamuela, Kohala, and Waimea.

May 9: 15:33:27.6*. Epicenter 19°22.1' north, 155°04.9' west, at a depth of 11 km. Magnitude 5.0. Felt Island-wide.

May 10: 04:50:40.9*. Epicenter 19°18.3' north, 155°01.4' west, at a depth of 10 km. Magnitude 3.1. Felt at Kalapana.

May 16: 22:38:46.0*. Epicenter 19°56.8' north, 155°05.7' west, at a depth of 47 km. Magnitude 3.0. Felt at Kilauea.

May 17: 12:52:58.4*. Epicenter 19°14.7' north, 155°25.4' west, at a depth of 34 km. Magnitude 3.6. Felt at Kealakekua.

May 22: 17:07:28.8*. Epicenter 19°02.4' north, 155°02.3' west, at a depth of 12 km. Magnitude 3.8. Felt at Kilauea.

May 24: 16:38:27.0*. Epicenter 21.2° north, 157.7° west, W., at a depth of about 33 km. Felt on the southeast coast of Oahu.

May 24: 17:59:59.8*. Epicenter 19°19.5' north, 155°07.7' west, at a depth of 5 km. Magnitude 3.8. Felt at Kealakekua and Kilauea.

May 25: 03:43:15.1*. Epicenter 19°23.8' north, 155°32.1' west, at a depth of 8 km. Magnitude 3.7. Felt at Kealakekua, Kilauea, and Waimea.

May 25: 18:01:49.7*. Epicenter 19°20.3' north, 155°07.6' west, at a depth of 4 km. Magnitude 3.3. Felt at Kilauea.

May 27: 09:19:20.0*. Epicenter 19°25.5' north, 155°17.3' west, at a depth of 19 km. Magnitude 3.3. Felt at Pahala.

June 2: 17:33:51.6*. Epicenter 19°20.1' north, 155°07.9' west, at a depth of 11 km. Magnitude 3.3. Felt at Hilo.

June 4: 03:32:56.3*. Epicenter 19°18.5' north, 155°12.7' west, at a depth of 10 km. Magnitude 3.7. Felt at Hilo and Pahala.

June 5: 14:43:41.3*. Epicenter 19°19.4' north, 155°13.7' west, at a depth of 9 km. Magnitude 3.7. Felt at Hilo, Kealakekua, Kilauea, and Pahala.

June 5: 14:54:46.3*. Epicenter 19°19.9' north, 155°14.6' west, at a depth of 9 km. Magnitude 3.0. Felt at Kilauea.

June 6: 09:41:46.9*. Epicenter 19°25.5' north, 155°27.0' west, at a depth of 11 km. Magnitude 4.4. Felt at Hilo, Kamuela, Kilauea, Mauna Loa, Paauilo, and Pahala.

June 6: 11:55:32.6*. Epicenter 19°21.3' north, 155°16.9' west, at a depth of 35 km. Magnitude 4.2. Felt Island-wide.

June 7: 01:41:26.2*. Epicenter 19°16.2' north, 155°11.2' west, at a depth of 10 km. Magnitude 4.0. Felt at Hilo, Kealakekua, Kilauea, and Pahala.

June 7: 01:50:31.8*. Epicenter 19°15.8' north, 155°11.1' west, at a depth of 10 km. Magnitude 3.1. Felt at Hilo and Kealakekua.

June 16: 19:04:53.1*. Epicenter 19°56.9' north, 155°06.9' west, at a depth of 61 km. Magnitude 3.4. Felt at Hilo.

June 18: 00:00:49.4*. Epicenter 19°21.4' north, 155°03.0' west, at a depth of 7 km. Magnitude 3.3. Felt at Pahala.

July 3: 06:57:36.6*. Epicenter 19°21.9' north, 155°12.0' west, at a depth of 5 km. Magnitude 3.0. Felt at Kilauea.

July 6: 11:37:24.2*. Epicenter 19°20.8' north, 155°21.6' west, at a depth of 32 km. Magnitude 3.5. Felt at Kealakekua.

July 13: 01:22:03.0*. Epicenter 19°12.2' north, 155°34.8' west, at a depth of 8 km. Magnitude 4.2. Felt at Kealakekua, Kilauea, and Pahala.

July 20: 04:47:13.1*. Epicenter 19°23.7' north, 155°54.8' west, at a depth of 10 km. Magnitude 3.6. Felt at Kealakekua.

August 6: 18:42:17.2*. Epicenter 19°41.9' north, 156°02.7' west, at a depth of 4 km. Magnitude 3.5. Felt at Kohala.

September 3: 09:40:09.4*. Epicenter 19°20.0' north, 155°25.0' west, at a depth of 31 km. Magnitude 4.3. Felt on Islands of Hawaii and Oahu.

October 11: 12:00:07.2*. Epicenter 20°20.0' north, 155°03.3' west, at a depth of 5 km. Magnitude 3.0. Felt at Hilo.

October 14: 12:55:31.9*. Epicenter 19°22.9' north, 155°04.2' west, at a depth of 8 km. Magnitude 4.0. Felt at Hilo and Kilauea.

October 22: 03:26:30.0*. Epicenter 19°22.7' north, 155°23.5' west, at a depth of 11 km. Magnitude 3.3. Felt at Hilo, Mountain View, and Pahala.

November 5: 05:21:24.6*. Epicenter 19°58.5' north, 155°21.4' west, at a depth of 9 km. Magnitude 3.6. Felt at Hilo, Honokaa, and Paauilo.

November 5: 05:44:06.1*. Epicenter 19°59.6' north, 155°21.5' west, at a depth of 10 km. Magnitude 3.7. Felt at Hilo, Honokaa, Kilauea, and Paauilo.

November 5: 06:57:11.0*. Epicenter 19°55.4' north, 155°20.0' west, at a depth of 9 km. Magnitude 3.5. Felt at Honokaa, Kilauea, and Paauilo.

November 5: 07:00:07.3*. Epicenter 19°59.1' north, 155°21.5' west, at a depth

of 9 km. Magnitude 3.4. Felt at Honokaa and Paauiilo.

November 5: 09:26:38.9*. Epicenter 20°00.7' north, 155°19.7' west, at a depth of 10 km. Magnitude 3.7. Felt at Hilo and Paauiilo.

November 9: 19:12:12.2*. Epicenter 19°10.6' north, 155°30.7' west, at a depth of 8 km. Magnitude 4.5. Felt at Hilo, Kealakekua, Kilauea, Naalehu, and Pahala.

November 10: 21:20:25.7*. Epicenter 19°57.9' north, 155°21.3' west, at a depth of 10 km. Magnitude 3.1. Felt at Paauiilo.

November 22: 14:05:44.0*. Epicenter 19°33.5' north, 155°05.2' west, at a depth of 17 km. Magnitude 3.6. Felt at Hilo, Kilauea, Mountain View, Paauiilo, and Pahala.

November 23: 13:34:16.0*. Epicenter 19°53.1' north, 155°31.0' west, at a depth of 32 km. Magnitude 3.2. Felt at Paauiilo and Pahala.

November 24: 09:12:22.9*. Epicenter 19°41.8' north, 156°03.5' west, at a depth of 35 km. Magnitude 4.5. Felt on northern half of island.

November 30: 23:56:23.3*. Epicenter 19°57.9' north, 155°20.3' west, at a depth of 9 km. Magnitude 3.5. Felt at Paauiilo.

December 6: 22:34:29.9*. Epicenter 19°20.2' north, 155°06.3' west, at a depth of 10 km. Magnitude 3.1. Felt at Mountain View.

December 24: 19:39:34.1*. Epicenter 19°30.0' north, 155°08.9' west, at a depth of 25 km. Magnitude 3.2. Felt at Hilo and Kilauea.

December 25: 03:28:26.7*. Epicenter 19°21.4' north, 155°17.2' west, at a depth of 32 km. Magnitude 3.3. Felt at Kilauea and Pahala.

December 27: 16:59:44.0*. Epicenter 19°19.1' north, 155°14.6' west, at a depth of 9 km. Magnitude 4.1. Felt at Hilo and Kilauea.

December 27: 19:37:20.8*. Epicenter 19°19.0' north, 155°13.3' west, at a depth of 10 km. Magnitude 3.7. Felt at Hilo, Kealakekua, and Paauiilo.

December 29: 06:00:52.7*. Epicenter 19°20.1' north, 155°28.7' west, at a depth of 10 km. Magnitude 3.6. Felt at Pahala.

PANAMA CANAL ZONE

[75th Meridian Time]

August 17: 23:04:37.4*. Epicenter 7.5° north, 80.7° west, Panama, W. Magnitude 4.4. Felt at Balboa.

December 23: 07:20:53.3*. Epicenter 10.0° north, 78.8° west, north of Panama, W. Magnitude 5.0. Intensity III at Balboa Heights.

PUERTO RICO

[60th Meridian Time]

January 28: 08:46:54.0*. Epicenter 19.4° north, 66.3° west, Puerto Rico region, W. Magnitude 4.4. Felt at San Juan.

January 29: 07:06:23.1*. Epicenter 19.5° north, 66.2° west, Puerto Rico region, W. Felt at San Juan.

March 20: 11:38:41*. Felt at San Juan.

August 1: 09:06:49.1*. Virgin Islands earthquake felt at Humacao and San Juan.

September 28: 02:02. Intensity IV at Boca, Central San Francisco, Guayanilla.

December 25: 17:32:27.3*. Epicenter 15.8° north, 59.7° west, Leeward Islands, W. Magnitude 7.2. Felt at San Juan.

VIRGIN ISLANDS

[60th Meridian Time]

August 1: 09:06:49.1*. Epicenter 18.8° north, 64.4° west, Virgin Islands, W. Felt in Virgin Islands, and at Humacao and San Juan, P. R.

PRINCIPAL EARTHQUAKES OF THE WORLD DURING 1969

Listed in this section are (1) earthquakes of magnitude greater than $6\frac{3}{4}$ and those of smaller magnitude which were locally destructive and caused casualties; (2) earthquakes of unusual interest.

Date	Origin time G.M.T.	Region	Coordinates		Remarks*
			Lat.	Long.	
	<i>h m s</i>		<i>deg</i>	<i>deg</i>	
Jan. 3-	03 16 38.1	Iran-USSR border -----	37.1 N.	57.9 E.	50 killed, 300 injured, and severe property damage in Khorassan Province, Iran. Depth 11 km. Mag. 5.2, W.
Jan. 5-	13 26 39.9	Solomon Islands -----	8.0 S.	158.9 E.	Slight damage on Santa Isabel Island. Depth 47 km. Mag. 7.5, P.
Jan. 6-	15 39 00.9	Santa Cruz Islands -----	10.5 S.	164.5 E.	Not felt. Depth 32 km. Mag. 7.1, P.
Jan. 19-	07 02 04.4	Hokkaido, Japan -----	45.0 N.	143.2 E.	Felt on northern Hokkaido. Depth 204 km. Mag. 7, P.
Jan. 24-	02 33 03.5	Fiji Islands region -----	21.9 S.	179.6 W.	Not felt. Depth 595 km (D). Mag. 7.0, P.
Jan. 30-	10 29 40.4	Talaud Islands -----	4.8 N.	127.4 E.	Felt on Mindanao and in Visayan Islands. Depth 70 km (G). Mag. 7.2, P.
Feb. 10-	22 58 05.8	South of Fiji Islands ----	22.7 S.	178.6 E.	Not felt. Depth 673 km (G). Mag. 6.9, P.
Feb. 23-	00 36 56.6	Celebes Island (Sulawesi) -----	3.1 S.	118.9 E.	64 killed, 97 injured, and 1,287 structures damaged in Madjene and environs. Tsunami took 600 lives (press). Depth 13 km. Mag. 6.9, W.
Feb. 28-	02 40 32.5	North Atlantic Ocean ---	36.0 N.	10.6 W.	13 killed (11 Morocco, 2 Portugal), 80 injured, and extensive property damage in Portugal, Morocco, and Spain. Small tsunami generated. Depth 22 km. Mag. 8.0, W.
Mar. 27-	12 41 35.9	Talaud Islands -----	4.8 N.	127.5 E.	Not felt. Depth 32 km. Mag. 7.0, P.
Mar. 28-	01 48 30.4	Turkey -----	38.6 N.	28.4 E.	11 killed and heavy damage in Alasehir region. Depth 9 km. Mag. 6.4, W.
Mar. 29-	09 15 54.1	Ethiopia -----	12.0 N.	41.2 E.	24 killed, 165 injured, and severe damage at Sardo. Depth N. Mag. 6.3, W.
Mar. 31-	07 15 54.4	Red Sea -----	27.7 N.	34.0 E.	2 killed, 16 injured, and heavy damage in United Arab Republic. Depth N. Mag. 7-7 $\frac{1}{4}$, P.
Apr. 3-	22 12 23.8	Albania -----	40.7 N.	19.9 E.	1 killed, 65 injured, and 1,000 houses heavily damaged or destroyed. Depth N. Mag. 5.5, W.
May 14-	19 32 54.2	Andreanof Islands -----	51.3 N.	179.9 W.	Felt on Adak and Amchitka. Depth 21 km. Mag. 7.0, W.
July 18-	05 24 48.0	Northeastern China -----	38.3 N.	119.4 E.	Heavy damage reported in China. Depth N. Mag. 7.3, W.

PRINCIPAL EARTHQUAKES OF THE WORLD DURING 1969—Continued

Date	Origin time G.M.T.	Region	Coordinates		Remarks*
			Lat.	Long.	
	<i>h m s</i>		<i>deg</i>	<i>deg</i>	
July 25-	22 49 41.3	Eastern China -----	21.6 N.	111.9 E.	Unconfirmed total of 3,000 killed. Depth N. Mag. 5.9.
Aug. 5-	02 13 09.6	Molucca Passage -----	1.3 N.	126.2 E.	Felt on Celebes. Depth 34 km. Mag. 7.2, P.
Aug. 11-	21 27 39.4	Kuril Islands -----	43.5 N.	147.4 E.	Some damage. Felt widely. Small tsunami observed. Depth 28 km. Mag. 7.8, W.
Aug. 11-	23 52 56.3	Molucca Passage -----	1.7 N.	126.5 E.	Felt at Manado, Celebes. Depth 34 km. Mag. 7.0, W.
Sept. 29-	20 03 32.8	Republic of South Africa -----	32.9 S.	19.7 E.	12 killed, much property damage in Tulbagh and Wolseley. Depth N. Mag. 6.3, W.
Oct. 1-	05 05 43.2	Peru -----	11.9 S.	75.1 W.	136 killed, 216 injured, and villages of Lampa and Chilifruta destroyed. Depth 4 km. Mag. 6.4, P.
Oct. 2-	04 56 45.5	Northern California -----	38.5 N.	122.7 W.	Over \$7 million property damage in Santa Rosa area. Several were injured. Depth 2 km. Mag. 5.2, P.
Oct. 26-	15 36 51.8	Yugoslavia -----	44.9 N.	17.3 E.	20 killed, 150 injured, and 65,000 persons homeless. Extensive damage in Banja Luka and nearby villages. Depth N. Mag. 6, P.
Oct. 27-	08 10 58.3	----- do -----	44.9 N.	17.2 E.	Fatalities listed above (20) are for both earthquakes. Much damage in and around Banja Luka. Depth N. Mag. 6, P.
Nov. 20-	01 00 09.0	West Virginia -----	37.4 N.	81.0 W.	One of the few earthquakes to center here in recorded history. Slight property damage. Felt in eight states. Depth 3 km. Mag. 4.3, W.
Nov. 21-	02 05 35.3	Off west coast of northern Sumatra -----	2.1 N.	94.6 E.	Not felt. Depth 20 km (G). Mag 7.7, W.
Nov. 22-	23 09 37.2	Near east coast of Kamchatka -----	57.8 N.	163.5 E.	Slight tsunami recorded on tide gages in Alaska. Depth N. Mag. 7.3, W.
Dec. 25-	21 32 27.3	Leeward Islands -----	15.8 N.	59.7 W.	Minor damage in the region. Slight tsunami recorded. Depth 7 km. Mag. 7.2, W.

*Abbreviations in this column are as follows:

Following magnitude values: P, computed by Pasadena; W, computed by the NEIC office in Rockville.

Following depth values: G, restrained at that value by geophysicist and not freely determined in solution; D, restrained to agree with reported depth phases; N, restrained to normal (33 km) when depth is poorly determined for shallow or small shocks.

Miscellaneous Activities

GEODETIC WORK OF SEISMOLOGICAL INTEREST

The program of repeating geodetic control surveys to detect horizontal and vertical movement in the earth's crust was continued in 1969. Surveys for the study of horizontal movements were made by the Coast and Geodetic Survey in the following areas of California and Nevada:

California

Vicinity of Fort Ross.—A six-station triangulation net in this area was reobserved in 1969. The net is near the California coast, about 95 kilometers northwest of San Francisco. The previous surveys were made in 1876 and 1906. After the severe earthquake of 1906, the net was reobserved to determine the magnitude of relative displacement between stations on opposite sides of the San Andreas Fault. Results of the 1906 survey, when compared with results of 1876, disclosed right-lateral displacement of 3.9 meters. Although changes in some of the observed angles (1906 and 1969) were significant, the results did not indicate slippage between points on opposite sides of the fault. Strain computations show the average value for total shear is 69 parts per million (p.p.m.), or about 1 p.p.m. annually during the 63-year interval. The average value for direction of maximum positive shear is 130 degrees, approximately the same as the direction of the fault.

Bodega Bay.—This locality is about 27 kilometers southeast of the Fort Ross area. A triangulation-trilateration network of

three quadrilaterals with sides ranging in length from 1 to 2.5 kilometers, straddling the San Andreas Fault, was established by the California State Department of Water Resources in February 1968. A resurvey was accomplished by the Coast and Geodetic Survey in November 1969. In each of the two surveys, all sides were measured with Model 6 Geodimeters; the small differences in the measurements were well within the expected observational errors. This was also true for the small changes in the observed angles. There was no indication of slippage along the fault during this 20-month interval.

San Francisco Bay Area.—Part of a large net over the Bay area was reobserved in the latter part of 1969, but the results have not been fully evaluated. One of the lines in the net, connecting stations MOCHO and MOUNT DIABLO (established in 1875), has been used as a reference line for many of the crustal movement investigations in this area. The 1969 values for azimuth and length over the line are in very close agreement with results obtained from previous surveys. These results verify the fact that the selection of this line as a reference was an excellent choice.

Resurveys of four small fault-crossing nets in the Bay area, completed in 1969, are discussed below.

During the 2-year interval December 1967 to November 1969, the annual rate of movement at the Berkeley Memorial Stadium site was 5 millimeters. This is the same rate as that determined for the previous 1-year interval. In Hayward, observations at the UNION site continue to show

about the same rate of movement, 5 millimeters per year. The OSGOOD net at Irvington is 10 kilometers southeast of Hayward. The rate of movement continues at about 7 millimeters per year. In the vicinity of Camp Parks, Pleasanton, the annual rate of movement from 1965 to 1969 was 2 millimeters.

Vicinity of Hollister.—A resurvey of the HARRIS site was accomplished in March 1969. The results indicate right-lateral movement of 1.7 centimeters during the 17-month interval between the surveys, or an annual rate of 1.2 centimeters. Previous surveys at the Hollister Winery site, located about 6 kilometers to the southeast, disclosed about the same rate of movement, 1.2 centimeters per year.

Imperial Valley.—The epicenter of the large earthquake in southern California on April 8, 1968, was about 2 kilometers northwest of triangulation station OCOTILLO, established in 1939. This station, along with three other stations established in 1939, was used in a resurvey carried out in March 1969. Observations at station OCOTILLO showed right-lateral movement of 32 centimeters between the station and its azimuth mark. Immediately following the earthquake in 1968, Allen, et al.,¹ reported displacement of 30 centimeters near station OCOTILLO. A complete analysis of results from the 1969 survey will be given in 1970 in a Coast and Geodetic Survey Data Report of the Imperial Valley.

Aqueduct Surveys.—The cooperative project with the California State Department of Water Resources was continued during 1969. Resurveys were accomplished at five sites along the aqueduct route. At two of the sites, COLT and PEAR, the results did not indicate any significant changes from the previous surveys. At RANCH site, the accumulated changes from 1964 to 1969

did not form a uniform pattern of movement; however, the left-lateral shift was about 3 centimeters for the 5-year interval. Observations at the METTLER site showed instability at some stations in the net. Future surveys in this general area will be carried out at a new site, MEADE, located about 3 miles southwest of METTLER, where the White Wolf Fault crosses the aqueduct route. This new site was established and observed in June 1969, at about the same time observations were made at METTLER site.

Nevada

Reobservations of each of three Hollister-type triangulation figures were made in January-February 1969. The NRDS fault site, near ground zero for an underground blast, is approximately 110 miles at a geodetic azimuth 50 degrees from PAHROC fault site, and approximately 118 miles at an azimuth of 11 degrees from BLACK fault site. The results from the two surveys at each of the three sites did not indicate any significant earth movement in the areas of the three nets as a result of the underground atomic blast on December 19, 1968.

TSUNAMIS

Five tsunamis were reported to the Coast and Geodetic Survey during 1969, including three that were recorded on C&GS tide gages.

An earthquake in the Celebes (Sulawesi) on February 23 (3.1° south, 118.9° east) generated a tsunami which, according to press reports, caused 600 deaths and demolished four villages on the west coast of Celebes.

On February 28, an earthquake under the Atlantic Ocean west of Portugal (36.0° north, 10.6° west) generated a tsunami which was recorded on the coasts of Portugal, Spain, and Morocco. Maximum amplitudes recorded were 1.14 meters at Casablanca, Morocco, 0.48 meter at Chipiona,

¹"The Borrego Mountain, California, Earthquake of 9 April [G.m.t.] 1968: A Preliminary Report," *Bulletin of the Seismological Society of America*, Vol. 58, No. 3, June 1968.

Spain, and 0.45 meter at Leixoes, Portugal.

The August 11 Kuril Islands earthquake (43.5° north, 147.4° east) caused a minor tsunami that was recorded throughout the Pacific Basin. Maximum wave amplitude was 2.60 meters at Nemuro, Japan. Representative wave heights in other areas were: Shoya, Japan, 1.37 meters; Hachinohe, Japan, 1.10 meters; Kushiro, Japan, 0.94 meter; Midway Islands, 0.49 meter; Kahului, Hawaii, 0.43 meter; Nawiliwili, Hawaii, 0.18 meter; Baltra Island, Galapagos Islands, 0.15 meter; San Francisco, Calif., 0.06 meter; Attu, Alaska, 0.21 meter; La Punta, Callao, Peru, 0.37 meter; La Libertad, Ecuador, 0.30 meter; and Matarani, Peru, 0.27 meter. The USSR reported that its tide stations in the Kuril Islands re-

corded amplitudes of less than 1 meter. A *watch* was issued by the Pacific Tsunami Warning Center, Honolulu, Hawaii.

Another widely recorded minor tsunami was generated by an earthquake located near the east coast of Kamchatka (57.8° north, 163.5° east) on November 22. Maximum amplitudes recorded were 0.52 meter at Shemya, Alaska, 0.40 meter at Attu, Alaska, and 0.37 meter at Kahului, Hawaii. The Pacific Tsunami Warning Center issued a *watch* for this earthquake also.

On December 25, an earthquake in the Leeward Islands (15.8° north, 59.7° west) generated a minor tsunami that was recorded at Barbados, Antigua, and Dominica. Maximum amplitude was 0.46 meter at Barbados.

Fluctuations in Well-Water Levels

In 1943, the Coast and Geodetic Survey first published the section on well-water fluctuations in its annual *United States Earthquakes* series. Data for the years 1944 through 1949 appeared in the 1949 issue. From 1950 to the present, this section has been published annually.

The following material was compiled by the Water Resources Division of the U.S. Geological Survey. Table 1 lists fluctuations caused by various sources in wells throughout the country. Table 2 lists the date, time, and location of specific earthquakes that may have been associated with recorded fluctuations in well water. Also included are the states recording the fluctuations.

Complete information on earthquakes possibly associated with tabulations in table 1 may be obtained from the *Preliminary Determination of Epicenters* listings or *Seismological Bulletins*, both published by the National Earthquake Information Center. Another source is earthquake registers from seismograph stations nearest the locality.

WELL DESCRIPTIONS

Alaska

Well No. AK 67. Owner, U.S. Air Force, 61°13'36" north, 149°45'44" west, Glenn Highway, Elmendorf Air Force Base. Drilled, unused artesian well in sand and gravel, Pleistocene age. Depth, 198 feet; diameter, 6 inches.

Georgia

Well No. 27E2. Owner, U.S. Geological Survey, 35°50'00" north, 82°21'00.1" west.

Drilled observation artesian well in Ocala Limestone of late Eocene age. Depth, 647 feet; diameter, 4 inches; cased to 465 feet.

Well No. 33M4. Owner, U.S. Geological Survey, 31°38'44" north, 81°36'14" west. Drilled observation artesian well in Ocala Limestone of late Eocene age. Depth, 870 feet; diameter, 4 inches; cased to 538 feet.

Well No. 34H371. Owner, U.S. Geological Survey, 31°08'18" north, 81°29'36.9" west. Drilled observation artesian well in Ocala Limestone of late Eocene age. Depth, 700 feet; diameter, 3 inches; cased to 606 feet.

Well No. 34H374. Owner, U.S. Geological Survey, 31°09'53" north, 81°29'59" west. Drilled observation artesian well in Ocala Limestone of late Eocene age. Depth, 696 feet; diameter, 3 inches; cased to 527 feet.

Well No. 34H391. Owner, U.S. Geological Survey, 31°07'48" north, 81°29'13.1" west. Drilled observation artesian well in Ocala Limestone of late Eocene age. Depth, 1,159 feet; diameter, 6 inches; cased to 1,070 feet.

Well No. 34N89. Owner, U.S. Geological Survey, 31°52'14" north, 81°23'52.1" west. Drilled observation artesian well in Ocala Limestone of late Eocene age. Depth, 789 feet; diameter, 4 inches; cased to 410 feet.

Wisconsin

Well No. MI-45. Owner, Milwaukee Journal, 43°02'33" north, 87°54'55" west. Drilled, unused artesian well in Niagara

Dolomite, Silurian age. Depth, 1,015 feet; Shullsburg. Drilled, unused artesian well diameter, 8 to 5 inches; depth of casing, in Galena Dolomite and Platteville formation, Middle Ordovician age. Depth, 265 1,015 feet; ruptured 146 to 505 feet.

Well No. Lf-57. Owner, Coulthard Estate, 42°31'14" north, 90°16'11" west, 16 feet.

TABLE 1.—*Fluctuations in well-water levels during 1969*

County and/or. well number	Date	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
ALASKA						
			<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>
AK 316b -----	Apr. 14	1530	7.740	0.005	0.020	0.025
AK 17 -----	May 18	0900	62.21	.01	.01	.02
Do -----	July 18	0060±	60.795	.005	.010	.015
AK 67 -----	Aug. 6	0038	26.910	.005	0	.005
AK 316b -----	Aug. 6	0038	8.175	.01	.01	.02
AK 17 -----	Aug. 11	2230±	59.480	.09	.09	.18
GEORGIA						
Liberty 34N89 -----	Feb. 28	0215	-----	0.175	0.175	0.35
Dougherty 13L3 -----	Feb. 28	0225 ¹	42.35	.22	.22	.44
Charlton 27E2 -----	Feb. 28	0300 ¹	64.11	.18	.20	.38
Dawson 13KK1 -----	Feb. 28	0300 ¹	25.94	.02	.02	.04
Glynn 34H371 -----	Feb. 28	0300	+1.99	.07	.07	.14
Glynn 34H374 -----	Feb. 28	0300	+19.46	.09	.10	.19
Glynn 34H391 -----	Feb. 28	0300	+2.32	.08	.07	.15
Long 33M4 -----	Feb. 28	0310	38.47	.14	.13	.27
Glynn 33H127 -----	Feb. 28	0330	1.21	.075	.080	.155
Glynn 33H133 -----	Feb. 28	0330	12.19	.11	.10	.21
Charlton 27E2 -----	July 18	0600	65.19	-----	-----	.02
Glynn 33H133 -----	July 18	0610	14.44	.04	.01	.05
Dougherty 13L3 -----	July 18	0650 ¹	40.96	.035	.034	.069
Dawson 13KK1 -----	July 18	0700 ¹	27.42	-----	-----	.01
Glynn 33H133 -----	Aug. 11	2200	13.97	.41	.44	.85
Glynn 34H374 -----	Aug. 11	2200	21.18	.08	.10	.18
Charlton 27E2 -----	Aug. 11	2200	68.35	.43	.32	.75
Glynn 33H127 -----	Aug. 11	2230	2.55	.12	.11	.23
Glynn 34H371 -----	Aug. 11	2230	+ .76	.08	.06	.14
Long 33M4 -----	Aug. 11	2320	39.02	.12	.15	.27
Dawson 13KK1 -----	Aug. 11	2330	27.84	.05	.03	.08
Dougherty 13L3 -----	Aug. 11	2330 ¹	41.60	.29	.27	.56
Glynn 33H127 -----	Nov. 1	1100	1.19	.01	.01	.02
Dougherty 13L3 -----	Nov. 1	1120	42.35	.01	.01	.02
Charlton 27E2 -----	Nov. 21	0300 ¹	63.85	.02	.05	.07
Dougherty 13L3 -----	Nov. 21	0300 ¹	43.08	.06	.07	.13
Liberty 34N89 -----	Nov. 21	0300	-----	.02	.02	.04
Long 33M4 -----	Nov. 21	0300	40.08	.025	.025	.05
Thomas 14E15 -----	Nov. 21	0300 ¹	198.32	.17	.17	.34
Glynn 33H127 -----	Nov. 21	0400	2.11	.025	.02	.045

¹ Unable to check chart time.

TABLE 1.—Fluctuations in well-water levels during 1969—Continued

County and/or well number	Date	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
GEORGIA—Continued						
Glynn 33H133 -----	Nov. 21	0400	13.05	.03	.02	.05
Long 33M4 -----	Nov. 22	2320	40.13	.01	.01	.02
Dougherty 13L3 -----	Nov. 22	2330 ¹	43.07	.08	.08	.16
Thomas 14E15 -----	Nov. 22	2330 ¹	198.44	.18	.18	.36
Glynn 33H127 -----	Nov. 22	(²)	1.89	.02	.01	.03
Liberty 34N89 -----	Nov. 22	2345	-----	.02	.02	.04
Charlton 27E2 -----	Dec. 25	2130	63.20	.22	.22	.44
Thomas 14E15 -----	Dec. 25	2145	197.67	.27	.27	.54
Dawson 13KK1 -----	Dec. 25	2210 ¹	28.06	.02	.01	.03
Liberty 34N89 -----	Dec. 25	2230	-----	.18	.18	.36
Long 33M4 -----	Dec. 25	(²)	39.04	.11	.11	.22
IDAHO ²						
Elmore 2S-5E-36bbbl -----	Feb. 28	0245	285.13	0.03	0.02	0.05
Cassia 13S-21E-18bbcl -----	Feb. 28	0300	533.63	.05	.05	.10
Butte 6N-25E-3aaal -----	Feb. 28	0315	72.71	.03	.03	.06
Madison 7N-38E-23dbal -----	Feb. 28	0345	43.23	.05	.04	.09
Do -----	Feb. 28	0400	43.23	.27	.25	.52
Do -----	Feb. 28	0410	43.23	.20	.22	.42
Do -----	Feb. 28	0430	43.23	.08	.07	.15
Do -----	Feb. 28	0440	43.23	.04	.03	.07
Jerome 8S-19E-5dabl -----	Feb. 28	0445	273.80	.02	.01	.03
Madison 7N-38E-23dbal -----	Mar. 20	0900	43.81	.03	.01	.04
Do -----	Mar. 21	0530	43.78	.01	.02	.03
Do -----	Mar. 21	0715	43.77	.01	.02	.03
Do -----	Apr. 4	1530	44.06	.03	.02	.05
Butte 5N-31E-28cccl -----	May 14	1930	264.03	.03	.03	.06
Butte 3N-29E-14adbl -----	July 14	1815	453.14	.07	.03	.10
Madison 7N-38E-23dbal -----	July 18	0510	39.97	.04	.05	.09
Teton 4N-45E-13adal -----	July 18	0520	158.41	.01	.03	.04
Butte 4N-30E-7adbl -----	July 18	0615	317.63	.02	.03	.05
Butte 5N-31E-28cccl -----	July 18	0700	262.60	.03	.02	.05
Madison 7N-38E-23dbal -----	Aug. 11	2040	39.11	.11	.09	.20
Do -----	Aug. 11	2050	39.10	.18	.17	.35
Do -----	Aug. 11	2100	39.10	.12	.09	.21
Do -----	Aug. 11	2125	39.09	.06	.05	.11
Butte 5N-31E-28cccl -----	Aug. 11	2140	261.11	.25	.25	.50
Butte 3N-29E-14adbl -----	Aug. 11	2145	452.82	.04	.02	.06
Butte 4N-30E-7adbl -----	Aug. 11	2205	316.25	.13	.13	.26
Do -----	Aug. 11	2210	316.25	.14	.14	.28
Do -----	Aug. 11	2215	316.24	.10	.11	.21
Do -----	Aug. 11	2235	316.23	.05	.07	.12
Elmore 2S-5E-36bbbl -----	Aug. 11	2245	285.16	.02	.04	.06
Do -----	Aug. 11	2300	285.15	.03	.04	.07
Madison 7N-38E-23dbal -----	Aug. 17	1920	38.98	.55	.64	1.19
Teton 4N-45E-13adal -----	Aug. 17	1945	173.65	.12	.13	.25

¹ Unable to check chart time.² Time of occurrence for monthly gage believed to be accurate to ± 1 hour. Time for all other gages believed to be accurate to ± 30 minutes.

TABLE 1.—Fluctuations in well-water levels during 1969—Continued

County and/or well number	Date	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
IDAHO—Continued						
Butte 4N-30E-7adbl -----	Aug. 17	1945	316.02	.15	.18	.33
Jefferson 5N-32E-36addl -----	Aug. 17	2000	329.87	.04	.03	.07
Butte 5N-31E-28cccl -----	Aug. 17	2015	260.92	.14	.13	.27
Butte 3N-29E-14adbl -----	Aug. 17	2040	452.85	.19	.22	.41
Twin Falls 14S-15E-28bad2 -----	Aug. 17	2050	106.79	.04	.02	.06
Blaine 1S-19E-3ccb2 -----	Sept. 16	0500-0700	7.59	.01	.02	.03
Teton 4N-45E-13adal -----	Sept. 16	1330	184.75	.02	.03	.05
Elmore 2S-5E-36bbbl -----	Sept. 16	1445	285.28	.02	.03	.05
Butte 3N-29E-14adbl -----	Sept. 16	1510	452.77	.08	.10	.18
Butte 4N-30E-7adbl -----	Sept. 16	1510	315.38	.03	.05	.08
Jefferson 7N-34E-4cdcl -----	Sept. 16	1530	18.08	.04	.04	.08
Blaine 8S-26E-33bcbl -----	Nov. 1	0400-0600	105.15	.05	.07	.12
Butte 4N-30E-7adbl -----	Nov. 1	1115	315.27	.11	.15	.26
Elmore 2S-5E-36bbbl -----	Nov. 1	1120	285.37	.04	.03	.07
Butte 3N-29E-14adbl -----	Nov. 1	1145	451.71	.11	.11	.22
Cassia 13S-21E-18bbcl -----	Nov. 1	1145	551.83	.03	.03	.06
Madison 7N-38E-23dbal -----	Nov. 1	1150	39.07	.43	.45	.88
Butte 5N-31E-28cccl -----	Nov. 1	1200	259.62	.09	.10	.19
Butte 3N-29E-14adbl -----	Nov. 5	1815	451.98	.03	.05	.08
Madison 7N-38E-23dbal -----	Nov. 5	1820	39.02	.14	.10	.24
Butte 5N-31E-28cccl -----	Nov. 5	1845	259.57	.02	.03	.05
Butte 4N-30E-7adbl -----	Nov. 22	2345	315.33	.04	.05	.09
Madison 7N-38E-23dbal -----	Nov. 22	2350	39.72	.08	.11	.19
Do -----	Nov. 22	2400	39.73	.06	.08	.14
Blaine 2S-20E-lacc2 -----	Dec. 22	0000-0200	146.82	.03	.02	.05
Teton 4N-45E-13adal -----	Dec. 25	2110	197.12	.02	.02	.04
Butte 4N-30E-7adbl -----	Dec. 25	2150	315.18	.04	.07	.11
Madison 7N-38E-23dbal -----	Dec. 25	2200	40.42	.09	.07	.16
Butte 5N-31E-28cccl -----	Dec. 25	2220	258.14	.07	.08	.15
INDIANA						
Ma 32 -----	Aug. 11	2025-2245	10.98	0.26	0.19	0.45
Hr 8 -----	Aug. 11	2100-2130	13.33	.02	.01	.03
Fu 7 -----	Aug. 11	2215-2230	8.74	.01	.03	.04
Pu 6 -----	Aug. 11	2225-2315	9.659	.117	.098	.215
Dw 4 -----	Aug. 11	2240-2320	47.96	.02	.02	.04
Do -----	Aug. 17	1950-1955	48.30	.01	.03	.04
Pu 6 -----	Nov. 1	1025-1035	10.872	.026	.022	.048
Dw 4 -----	Nov. 1	1030-1035	48.78	.02	.01	.03
Ma 32 -----	Nov. 1	1035-1050	10.41	.13	.09	.22
Dw 4 -----	Nov. 22	2230-2235	47.93	.01	.01	.02
Pu 6 -----	Nov. 22	2315-2320	8.810	.010	.002	.012
Ma 32 -----	Nov. 22-23	2335-0015	9.38	.04	.08	.12
Pu 6 -----	Dec. 25	2045-2115	9.405	.030	.036	.066
Dw 4 -----	Dec. 25	2050-2055	48.65	0	.02	.02
Ma 32 -----	Dec. 25	2215-2300	10.24	.10	.11	.21

TABLE 1.—Fluctuations in well-water levels during 1969—Continued

County and/or well number	Date	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
NEVADA						
S19/60-9bccl -----	Mar. 20	0810	120.01	0.06	0.08	0.14
Do -----	Mar. 21	0450	120.32	.07	.08	.15
S17/50-36dcl -----	Apr. 4	1620	1.74	.03	.04	.07
Do -----	Sept. 23	2200	1.44	.04	.03	.07
Do -----	Oct. 2	0620	1.49	.02	.02	.04
Do -----	Oct. 2	0800	1.47	.02	.02	.04
S21/54-28bdI -----	Oct. 2	2200	23.28	.38	.46	.84
S17/50-36dcl -----	Oct. 8	1500	1.23	.06	.04	.10
WISCONSIN						
M1-45 -----	Feb. 28	0300	32.20	0.03	0.03	0.06
M1-120 -----	Feb. 28	0330	100.22	.03	0	.03
Do -----	May 14	1930	99.80	.02	.01	.03
Do -----	July 18	0545	98.28	.035	.015	.05
Do -----	Aug. 11	2150	97.53	.165	.19	.355
Do -----	Aug. 17	2040	97.44	.06	.07	.13
Do -----	Sept. 16	1450	98.12	.015	0	.015
Do -----	Nov. 21	0300	98.155	.025	.055	.080
Do -----	Nov. 22	2350	97.800	.020	.045	.065
Lf-57 -----	Dec. 25	2045	112.04	.32	.34	.66
M1-120 -----	Dec. 25	2150	96.885	.085	.080	.165

TABLE 2.—Earthquakes in 1969 believed to have caused fluctuations in well-water levels

Date		Origin time G.M.T.			Location	States recording fluctuations
		h	m	s		
Feb.	28----	02	40	32.5	North Atlantic Ocean -----	Georgia, Idaho, Wisconsin
Mar.	20----	08	17	41.9	Gulf of California (plus aftershocks) -----	Idaho, Nevada
Mar.	21----	03	07	41.9	Gulf of California -----	Indiana
Apr.	4----	16	16	17.2	Gulf of California -----	Idaho, Nevada
Apr.	14----	14	53	25.0	Kodiak Island region -----	Alaska
May	14----	19	32	54.2	Andreanof Islands -----	Idaho, Wisconsin
May	18----	08	44	03.6	Southern Alaska -----	Alaska
July	18----	05	24	48.0	Northeastern China -----	Alaska, Georgia, Idaho, Wisconsin
Aug.	6----	00	38	42.8	Southern Alaska -----	Alaska
Aug.	11----	21	27	39.4	Kuril Islands -----	Alaska, Georgia, Idaho, Indiana, Wisconsin
Aug.	17----	20	14	58.9	Gulf of California -----	Idaho, Indiana, Wisconsin
Sept.	16----	14	30	00.0	Southern Nevada (Nevada Test Site) -----	Nevada
Sept.	23----	22	37	22.6	Off coast of Jalisco, Mexico -----	Nevada
Oct.	2----	06	19	56.0	Northern California -----	Nevada
Oct.	2----	07	10	08.9	Northern California -----	Nevada
Oct.	2----	22	06	00.0	Rat Islands MILROW (AEC) -----	Nevada
Oct.	8----	14	30	00.0	Southern Nevada (Nevada Test Site) -----	Nevada, Georgia
Nov.	1----	11	08	20.9	Gulf of California -----	Idaho, Indiana
Nov.	5----	17	54	13.6	Off coast of California -----	Idaho, Georgia
Nov.	21----	02	05	35.3	Off west coast of northern Sumatra -----	Wisconsin
Nov.	22----	23	09	37.2	Near east coast of Kamchatka -----	Idaho, Georgia, Indiana, Wisconsin
Dec.	25----	21	32	27.3	Leeward Islands -----	Idaho, Georgia, Indiana, Wisconsin

Strong-Motion Seismograph Results

The Coast and Geodetic Survey has conducted an engineering seismology program in the United States and Latin America since 1932. The Survey, with the cooperation of state and municipal governments, private industry, and state and private educational institutions, has installed and maintained strong-motion seismographs and analyzed the seismograms. The results of the analysis have been published in Government bulletins and scientific journals, and the records, either originals or copies, have been made available to research scientists.

A list of strong-motion stations in the United States and Latin America is no longer included in this annual report. However, a report entitled *Strong-Motion Station Instrumental Data*, dated January 1970, is available upon request. The report gives the geographic location of each station, instrumental constants, and lists new stations and those removed during 1969. In addition, it contains a list of seismoscope sites in California, Alaska, and Arizona.

The number of strong-motion seismograph installations in the United States and Latin America increased from 289 in 1968 to 362 in December 1969. Seismoscope installations also increased, from 361 in 1968 to 377 in December 1969.

Figure 10 shows the locations of strong-motion sites in the United States and Central and South America. Table 3 gives a list of earthquakes recorded and records obtained on strong-motion instruments in 1969. The table necessarily has been edited to include a sampling of records of only the most important earthquakes.

Notes pertinent to this engineering seismology program may be found in preceding issues of the *United States Earthquakes* series and in *Earthquake Investigations in the Western United States, 1931-1964*. The latter is much broader in scope, containing data on structural and ground vibrations and detailed descriptions of the many activities which comprise the seismological program as a whole.

INTERPRETATION OF RECORDS

The analyses appearing in tables 4 and 5 are based on the assumption of simple harmonic motion. This refers especially to the computation of displacement from accelerograph records. As most accelerograph records are irregular in character, and the character of the longer-period waves is often obscured by the superposition of shorter-period waves of relatively large amplitudes, the estimates of displacement must be considered only rough approximations.

UNITS AND INSTRUMENTAL CONSTANTS

Quantitative results are expressed in c.g.s. units—centimeters or millimeters for displacement, and centimeters per second per second for acceleration. It is sometimes desirable to express acceleration in terms of the acceleration of gravity, indicated by g , which is equal to 980 cm/sec^2 . For practical purposes, point off three decimal places to the left to convert cm/sec^2 to an approximation of g .

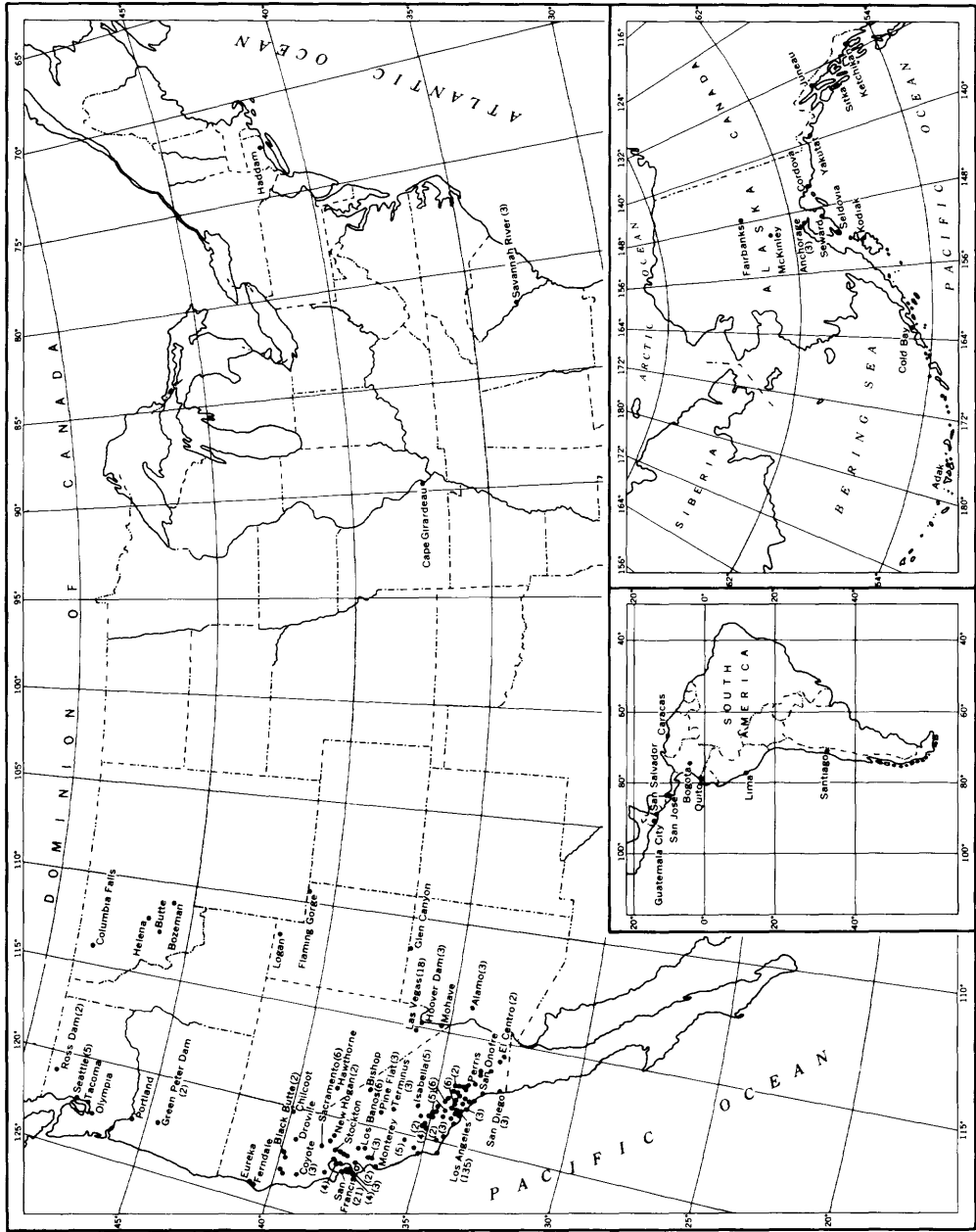


FIGURE 10.—Strong-motion station locations in the United States and Central and South America.

Most of the instruments have been adjusted so that each will register the maximum acceleration to be expected on the particular type of geological formation beneath the instrument. The following expectable earthquake accelerations were used in determining the accelerograph sensitivities: (a) rock foundation, 25 percent of gravity; (b) residual clay and shale, 40 percent of gravity; (c) alluvium, 70 percent of gravity; and (d) top floors of tall buildings, 100 to 200 percent of gravity. The four sensitivities may be roughly listed as 26, 19.5, 13, and 6.5 centimeters per 1.0 g, respectively.

Sensitivity of the seismographs is expressed as the deflection of the trace, or light spot, in centimeters for a constant acceleration of 1.0 g.

Damping ratio of the pendulum is the ratio between successive amplitudes when the pendulum oscillates.

SEISMOGRAM ILLUSTRATIONS

The reproductions of records (figs. 11 and 12) are tracings of the original records and must not be accepted as genuine copies.

The tabulated instrumental constants refer to the original records. The tracings are intended to show the nature of the data, rather than to furnish a means through which the reader can make his own measurements. Those who desire true copies for critical study should request them from the National Oceanic and Atmospheric Administration, National Ocean Survey, Rockville, Md. 20852.

Acceleration and displacement scales representing the equivalent of 0.1 g and 1 inch are indicated on the tracings of the acceleration and displacement curves. The scales provide the investigator with a quick means for making rough measurements on the published curves. The measurements of period on records of this nature are dependent largely on the judgment of the person reading them, and considerable latitude must be allowed in appraising their accuracy. The aim of such analyses is primarily to give a fair picture of the magnitudes of the various elements involved. The figures tabulated therefore should not be used for important studies without first referring to the illustrations for some idea of the nature of the original records.

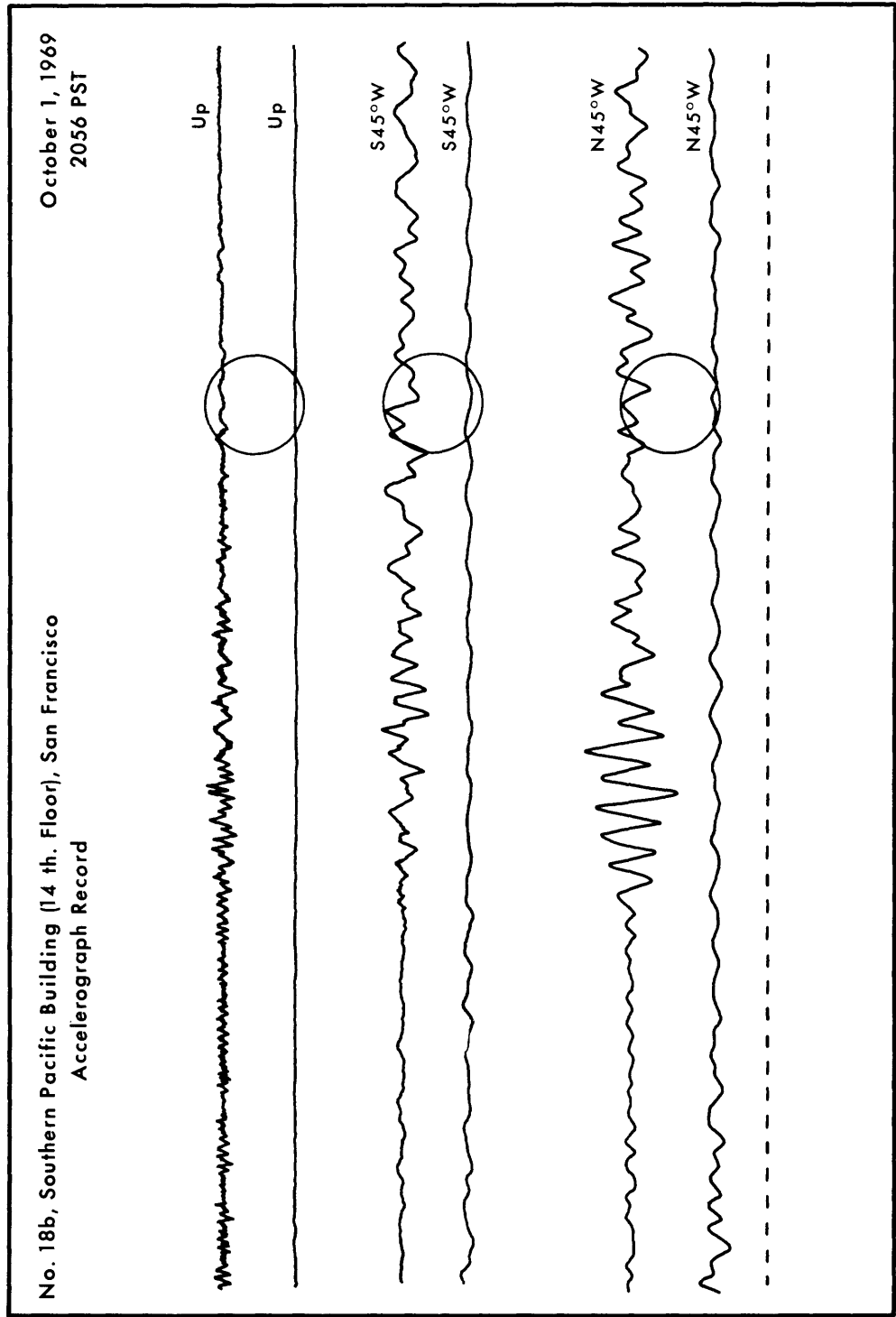


FIGURE 11.—Tracing of accelerograph record obtained at San Francisco, Calif., October 1 (20:56) .

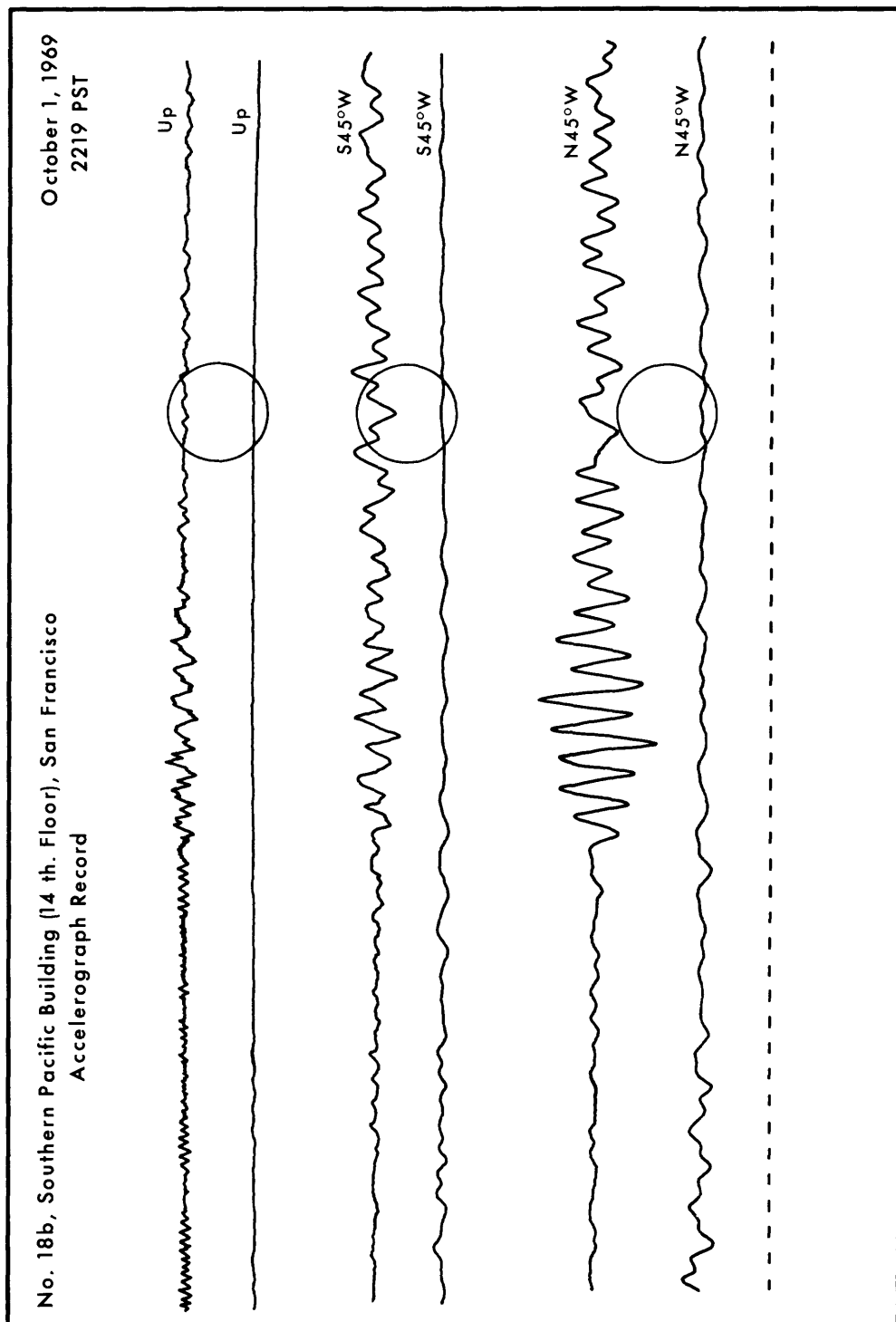


FIGURE 12.—Tracing of accelerograph record obtained at San Francisco, Calif., October 1 (22:19).

TABLE 3.—List of shocks recorded and obtained on strong-motion instruments in 1969

Date	Region and recording station	Number of records		
		Accelerograph	Survey displacement meter	Carter displacement meter
Jan. 9-----	<i>Central California</i>			
	Hollister, City Hall -----	1		1
Feb. 7-----	<i>Northern California</i>			
	Ferndale -----	1	1	
Apr. 28-----	<i>Southern California</i>			
	El Centro -----	1	1	1
	Long Beach, Terminal Island -----	1		
	Los Angeles:			
	Edison Buiding -----	1		
	445 Figueroa, subbasement -----	1*		
	19th floor -----	1*		
	39th floor -----	1*		
	1640 Marengo, 1st floor -----	1*		
	4th floor -----	1*		
	8th floor -----	1*		
	3407 W. 6th, basement -----	1*		
	4th floor -----	1*		
	8th floor -----	1*		
	4867 Sunset, basement -----	1*		
	2d floor -----	1*		
	7th floor -----	1*		
	Water and Power Building, basement --	1*		
	7th floor -----	1*		
	15th floor -----	1*		
	San Dimas, Puddingstone Reservoir ----	1*		
	San Bernardino, Hall of Records -----	1**		
	San Onofre -----	1*		
	Santa Ana, Engineering Building -----	1		
Oct. 1, 20:56----	<i>Northern California</i>			
	Oakland, City Hall, basement -----	1		
	Redwood City, APEEL Array Station No. 2 -	1*		
	San Francisco:			
	Alexander Building, basement -----	1		1
	Bethlehem Building, basement -----	1		1
	12th floor -----	1		1
	Federal Building -----	1		1
	390 Main St. -----	1		1
	Southern Pacific Building, basement --	1		1
	State Building, basement -----		1	
	San Pablo, Contra Costa Junior College --	1		1
Oct. 1, 22:19----	<i>Northern California</i>			
	Oakland City Hall, basement -----	1		
	Pleasant Hill, Diablo Valley College,			
	ground floor -----	1		1
	Redwood City, APEEL Array Station No. 1 -	1*		
Oct. 24-----	<i>Southern California</i>			
	Los Angeles:			
	1640 Marengo, 1st floor -----	1*		
	4th floor -----	1*		
	8th floor -----	1*		

TABLE 3.—List of shocks recorded and records obtained on strong-motion instruments in 1969—Continued

Date	Region and recording station	Number of records		
		Accelerograph	Survey displacement meter	Carter displacement meter
Oct. 27-----	Central California Hollister:			
	City Hall -----	1		1
	Sago Central -----	1***		
Nov. 15-----	Central California			
	Hollister, City Hall -----	1		1
	Pleasant Hill, Diablo Valley College, ground floor -----	1		1
	Redwood City, APEEL Array Station No. 1 --	1*		
	APEEL No. 2 -----	1*		
	San Francisco:			
	Alexander Building, basement -----	1		1
	Bethlehem Building, basement -----	1		1
	12th floor -----	1		1
	390 Main St. -----	1		1
	Southern Pacific Building basement ----	1		1
	State Building, basement -----		1	
	San Pablo, Contra Costa Junior College --	1		1
Nov. 17-----	Central California			
	Cholame-Shandon, Station No. 2 -----	1*		
	San Luis Obispo -----	1		
Dec. 10-----	Central California			
	Cholame-Shandon, Station No. 2 -----	1*		

*Instrument is AR-240.

**Instrument is RFT-250.

***Instrument is MO-2.

TABLE 4.—Summary of outstanding instrumental and noninstrumental data for 1969

Epicenter	Recording station and distance	Location of instrument	Intensity ¹	Acceleration	Displacement ²
FERNDALDE, CALIF., EARTHQUAKE OF FEBRUARY 7					
40°22' N., 124°30' W., northern California, B. VI*. Mag. 4.6.	Ferndale, City Hall, 50 miles.	Two-story wood-frame building on concrete ground floor.	VI	cm/sec ² 113	cm 0.47

¹ Reported intensity of earthquake at recording station.² Displacement is the maximum recorded at the station reporting the maximum acceleration of the earthquake. If displacement is much greater at another location, it is given along with the maximum acceleration at the same location.

*An asterisk following the intensity designation in the epicenter column indicates the maximum reported intensity of the earthquake.

TABLE 5.—Composite of strong-motion instrument data for 1969

Station and component	Instrument No.	T ₀	V	Sensitivity	e	Maximum				Remarks
						Acceleration		Displacement		
						Period	Amplitude	Period	Amplitude	
CENTRAL CALIFORNIA EARTHQUAKE OF JANUARY 9										
Hollister, City Hall:										
Up	238	0.067	123	13.8	8.0	0.54	1			
South	239	0.065	123	13.2	13.0	0.88	2			
West	240	0.065	122	13.4	9.0	0.56	1			
West	5	2.24	1		11.5			1.25	0.02	
North	6	2.12	1		10.5			1.82	0.07	
								1.96	0.06	
								0.95	0.02	
NORTHERN CALIFORNIA EARTHQUAKE OF FEBRUARY 7										
Ferndale:										
Up	247	0.068	125	13.8	9.0	0.36	33			
S44°W	248	0.067	125	13.3	9.0	0.48	14			
						0.24	113			
						0.39	25			
						0.68	25			
N46°W	249	0.065	123	12.3	10.0	0.17	96			
						0.36	28			
						0.75	19			
S46°E	RDM	9.3	1		10.0			1.64	0.37	
								0.73	0.24	
								0.77	0.13	
S44°W	LDM	9.8	1		12.0			1.01	0.35	
								1.15	0.47	
								1.04	0.11	
SOUTHERN CALIFORNIA EARTHQUAKE OF APRIL 28										
El Centro:										
Up	208	0.064	121	12.4	8.5	0.46	3			
						0.44	3			

South	206	0.066	124	13.2	8.0	0.66	15
						0.49	10
West	207	0.064	121	12.4	9.0	0.79	10
						0.59	14
East	CDM-29	6.43	1		7.5	0.57	16
						0.82	8
South	CDM-28	6.77	1		9.0		
North	RDM	10.10	1		7.5		
East	LDM	9.90	1		10.0		
Long Beach, Terminal Island:							
Up	1004	0.068	121	13.8	8.0	0.46	1
						0.35	1
S69°W	1005	0.067	120	13.5	10.0	0.39	3
						0.75	2
N21°W	1006	0.067	116	12.9	11.0	0.40	2
						0.63	2
Los Angeles, Edison Building:							
Up	268	0.065	120	12.9	9.0	0.34	2
						0.32	2
S38°W	269	0.066	121	13.2	9.0	0.33	1
						0.34	2
N52°W	270	0.066	120	13.0	9.0	0.47	1
						0.24	2
						0.23	2
						0.35	2
Los Angeles, 445 Figueroa, subbasement:							
Down	460	0.052	115	7.7	9.0	0.40	3
						0.31	2
N52°W	444	0.056	98.4	7.8	12.0	0.27	2
						0.36	3

TABLE 5.—Composite of strong-motion instrument data for 1969—Continued

Station and component	Instrument No.	T ₀	V	Sensitivity	e	Maximum				Remarks
						Acceleration		Displacement		
						Period	Ampli- tude	Period	Ampli- tude	
SOUTHERN CALIFORNIA EARTHQUAKE OF APRIL 28—Continued										
S38°E	417	0.056	99	7.7	8.0	0.41 0.40	2 3			
Los Angeles, 445 Figueroa, 19th floor: Down	502	0.055	99	7.5	10.0	0.34 0.35	5 5			
N52°W	403	0.055	98.9	7.5	9.5	0.29 0.28	4 5			
S38°E	433	0.056	96.6	7.6	9.5	0.41 0.30	4 4			
Los Angeles, 445 Figueroa, 39th floor: Down	505	0.054	110	7.8	11.0	0.30 0.31	9 10			
N52°W	438	0.053	113	7.8	8.5	0.36 0.90	6 5			
N38°E	507	0.053	112	7.9	10.5	0.38 0.56 0.36 0.45 0.84	3 6 6 4 5			
Los Angeles, 1640 Marengo, 1st floor: Down	419	0.048	126	7.6	9.0	0.31 0.34	3 3			
S52°W	420	0.051	119	7.6	9.0	0.27 0.31 0.36	5 5 4			
S38°E	434	0.053	111	7.6	9.0	0.34 0.32 0.31	7 6 5			
Los Angeles, 1640 Marengo, 4th floor: Down	427	0.051	119	7.6	10.0	0.29 0.39	2 2			

S52°W	448	0.051	119	7.6	9.0	0.65 0.60 0.58 0.55 0.59 0.62 0.65	9 10 10 4 7 6 5	---	---
N38°W	440	0.055	101	7.6	8.0	---	---	---	---
Los Angeles, 1640 Marengo, 8th floor:									
Down	449	0.054	106	7.6	10.0	0.28 0.29 0.60 0.53 0.53 0.67 0.71 0.58	3 3 14 20 8 10 12 10	---	---
S52°W	447	0.052	112	7.6	12.0	---	---	---	---
N38°W	471	0.052	112	7.6	10.0	---	---	---	---
Los Angeles, 3407 W. 6th, basement:									
Down	506	0.054	117	8.5	10.5	---	---	---	---
South	426	0.053	127	8.7	10.0	0.24 0.35 0.37 0.28	2 3 4 4	---	---
East	397	0.051	117	7.6	9.5	---	---	---	---
Los Angeles, 3407 W. 6th, 4th floor:									
Down	342	0.054	102	7.3	12.0	0.19 0.31 0.35 0.41 0.26 0.32 0.28	1 3 4 3 6 4 5	---	---
South	362	0.053	111	7.7	10.5	---	---	---	---
East	415	0.057	97	7.7	10.0	---	---	---	---
Los Angeles, 3407 W. 6th, 8th floor:									
Down	509	0.057	106	8.4	8.0	0.18 0.17 0.42 0.44 1.33	2 2 5 4 5	---	---
South	404	0.053	111	7.7	11.0	---	---	---	---

Not measurable.

TABLE 5.—Composite of strong-motion instrument data for 1969—Continued

Station and component	Instrument No.	T ₀	V	Sensitivity	ε	Maximum				Remarks
						Acceleration		Displacement		
						Period	Ampli- tude	Period	Ampli- tude	
SOUTHERN CALIFORNIA EARTHQUAKE OF APRIL 28—Continued										
East -----	439	0.053	111	7.7	10.0	0.33 0.29 0.43 1.28	5 7 8 5	----- ----- ----- -----	----- ----- ----- -----	Not measurable.
Los Angeles, 4867 Sunset, basement:										
Down -----	V	0.049	127	7.6	10.0	0.30 0.31 0.37 0.43 0.33 0.35 0.35 0.36	2 2 3 4 3 3 4 4	----- ----- ----- ----- ----- ----- ----- -----	----- ----- ----- ----- ----- ----- ----- -----	
S89°W -----	155	0.049	129	7.7	9.0					
S01°E -----	166	0.047	139	7.6	9.5					
Los Angeles, 4867 Sunset, 2d floor:										
Down -----	172	0.048	134	7.6	10.0	-----	-----	-----	-----	
S01°E -----	175	0.049	127	7.6	8.5	0.41 0.34 0.34 0.42 0.37 0.35	5 4 6 6 4 3	----- ----- ----- ----- ----- -----	----- ----- ----- ----- ----- -----	
N89°E -----	139	0.051	119	7.7	9.0					
Los Angeles, 4867 Sunset, 7th floor:										
Down -----	169	0.048	131	7.6	9.5	0.40 0.47 0.37 0.32 0.45 0.31 0.36	2 29 6 11 12 11 12	----- ----- ----- ----- ----- ----- -----	----- ----- ----- ----- ----- ----- -----	
S89°W -----	171	0.052	112	7.5	9.5					
S01°E -----	-----	0.048	136	7.7	7.5					

Los Angeles, Water and Power Building, basement: Down ----- N50°W ----- S40°W -----	346	0.053	108	7.5	11.0	0.31	2	-----	-----
	323	0.051	115	7.5	9.5	0.38	3	-----	-----
	288	0.053	106	7.5	10.0	0.25	1	-----	-----
Los Angeles, Water and Power Building, 7th floor: Down ----- N50°W ----- S40°W -----	233	0.057	99	7.9	9.0	0.26	2	-----	-----
	242	0.058	95.7	7.9	17.0	0.18	4	-----	-----
						0.24	5	-----	-----
						0.32	4	-----	-----
	316	0.052	117	7.9	11.0	0.36	5	-----	-----
						0.37	4	-----	-----
						0.31	7	-----	-----
Los Angeles, Water and Power Building, 15th floor: Down ----- N50°W ----- S40°W -----	290	0.053	111	7.6	7.0	0.27	2	-----	-----
						0.24	3	-----	-----
	285	0.052	113	7.6	9.0	0.30	5	-----	-----
						0.27	5	-----	-----
	310	0.052	113	7.6	8.5	0.27	3	-----	-----
						0.34	5	-----	-----
						2.51	6	-----	-----
San Dimas, Puddingstone Reservoir: Down ----- N55°E ----- N35°W -----	321	0.050	117	7.4	11.0	0.34	4	-----	-----
						0.40	4	-----	-----
						0.31	4	-----	-----
	351	0.052	110	7.5	12.5	0.47	7	-----	-----
						0.38	5	-----	-----
						0.41	5	-----	-----
	268	0.051	114	7.5	11.0	0.43	8	-----	-----
						0.43	8	-----	-----
San Bernardino, Hall of Records: Down ----- East -----	128	0.046	35.6	7.4*	9.5	0.32	3	-----	-----
						0.41	5	-----	-----
	129	0.047	33.2	7.4*	8.5	0.41	11	-----	-----
						0.50	7	-----	-----
						0.39	5	-----	-----

TABLE 5.—Composite of strong-motion instrument data for 1969—Continued

Station and component	Instrument No.	T ₀	V	Sensitivity	e	Maximum				Remarks
						Acceleration		Displacement		
						Period	Amplitude	Period	Amplitude	
SOUTHERN CALIFORNIA EARTHQUAKE OF APRIL 28—Continued										
North	130	0.046	36.2	7.6*	13.0	0.22	9			
San Onofre:	Down	304	113	7.6	10.5	0.33	6			
						0.30	5			
N33° E	329	0.053	114	8.0	10.0	0.12	4			
N57° W		392	115	7.6	11.0	0.11	3			
						0.14	2			
						0.19	3			
		392	115	7.6	11.0	0.26	3			
						0.21	5			
						0.22	4			
Santa Ana, Engineering Building:										
Up	1022	0.062	112	10.9	8.0	0.39	1			
S4° E		1023	117	10.9	8.0	0.26	1			
						1.38	2			
						0.43	2			
S86° W		1024	113	10.9	8.0	0.39	4			
						0.46	2			
						0.28	5			
S4° E	B	4.64	1	---	10.0	0.34	2			
						0.35	2			
N86° E	A	4.74	1	---	12.0			2.93	0.17	
								1.65	0.09	
								2.99	0.15	
								2.38	0.28	
								1.88	0.13	
								2.29	0.14	
NORTHERN CALIFORNIA EARTHQUAKES OF OCTOBER 1										
Oakland, City Hall, basement:										
Up	235	0.065	121	12.4	9.0	0.17	2			First shock.

N26°E	236	0.066	119	13.1	10.0	0.18	5	---	---	---	Second shock.
S64°E	237	0.067	115	12.6	10.0	0.22	6	---	---	---	
Oakland, City Hall, basement:											
Up											
N26°E	235	0.065	121	12.4	9.0	0.12	4	---	---	---	
S64°E	236	0.066	119	13.1	10.0	0.40	13	---	---	---	
	237	0.067	115	12.6	10.0	0.22	6	---	---	---	
Pleasant Hill, Diablo Valley College, ground floor:											
Up	1067	0.071	121	13.8	10.0	0.25	2	---	---	---	First shock.
North	1068	0.073	123	15.4	8.0	0.40	5	---	---	---	
East	1069	0.071	113	13.8	10.0	0.50	7	---	---	---	
North	---	4.30	1	---	10.0	---	---	1.00	0.18	---	
West	---	4.30	1	---	13.0	---	---	1.41	0.16	---	
Pleasant Hill, Diablo Valley College, ground floor:											
Up	1067	0.071	121	13.8	10.0	0.37	2	---	---	---	Second shock.
North	1068	0.073	123	15.4	8.0	0.40	9	---	---	---	
East	1069	0.071	113	13.8	10.0	0.46	8	---	---	---	
North	---	4.30	1	---	10.0	---	---	1.20	0.18	---	
West	---	4.30	1	---	13.0	---	---	1.00	0.12	---	
Redwood City, APEEL Array Station No. 1:											
Down	431	0.049	112	7.6	10.0	0.53	2	---	---	---	First shock.
N47°E	129	0.046	91.4	7.6	10.0	0.70	11	---	---	---	
N43°W	127	0.048	96.6	7.6	9.0	0.60	18	---	---	---	
Redwood City, APEEL Array Station No. 1:											
Down	431	0.049	112	7.6	10.0	0.36	2	---	---	---	Second shock.
N47°E	129	0.046	91.4	7.6	10.0	0.48	28	---	---	---	
N43°W	127	0.048	96.6	7.6	9.0	0.66	26	---	---	---	
Redwood City, APEEL Array Station No. 2:											
Down	---	0.047	100	7.6	10.0	0.40	2	---	---	---	First shock.
N47°E	---	0.048	100	7.6	10.0	0.77	12	---	---	---	
N43°W	---	0.046	100	7.6	10.0	0.60	17	---	---	---	
Redwood City, APEEL Array Station No. 2:											
Down	---	0.047	100	7.6	10.0	0.50	9	---	---	---	Second shock.
N47°E	---	0.048	100	7.6	10.0	0.60	21	---	---	---	
N43°W	---	0.046	100	7.6	10.0	0.60	21	---	---	---	
San Francisco, Alexander Building, basement:											
Up	199	0.064	117	12.4	8.0	0.20	3	---	---	---	First shock.
N09°W	198	0.065	118	12.9	10.0	0.33	8	---	---	---	

North	III	0.046	120	6.8	10.0	0.72	18	1.73	0.68
West		3.90	1		9.0			1.63	0.47
South		3.90	0.9		11.0				
San Francisco, 390 Main Street:									
Up	292	0.080	119	19.1	8.0	0.18	4		First shock.
S45°W	293	0.079	121	18.9	10.0	0.18	7		
N45°W	294	0.080	116	18.2	9.0	0.22	11		
S45°W	69	3.50	1		9.0			0.80	0.03
S45°E	70	2.70	1		6.0			1.60	0.09
San Francisco, 390 Main Street:									
Up	292	0.080	119	19.1	8.0	0.13	4		Second shock.
S45°W	293	0.079	121	18.9	10.0	0.12	9		
N45°W	294	0.080	116	18.2	9.0	0.15	12		
S45°W	69	3.50	1		9.0			2.00	0.05
S45°E	70	2.70	1		6.0			1.70	0.12
San Francisco, Southern Pacific Building, basement:									
Up	196	0.065	115	12.4	10.0	0.49	7		First shock.
N45°W	195	0.067	117	13.3	10.0	0.54	16		
N45°E	194	0.067	116	12.9	11.0	0.20	13		
N45°W	43	3.97	1		11.0			0.90	0.29
S45°W	42	3.44	1		14.0			1.17	0.14
San Francisco, Southern Pacific Building, basement:									
Up	196	0.065	115	12.4	10.0	0.53	8		Second shock.
N45°W	195	0.067	117	13.3	10.0	0.53	20		
N45°E	194	0.067	116	12.9	11.0	0.50	16		
N45°W	43	3.97	1		11.0			0.70	0.32
S45°W	42	3.44	1		14.0			1.00	0.15
San Francisco, State Building, basement:									
S81°W	Right	10.0	1		10.0			0.50	0.10
N09°W	Left	9.9	1		10.0			1.40	0.10
San Francisco, State Building, basement:									
S81°W	Right	10.0	1		10.0			0.70	0.13
N09°W	Left	9.9	1		10.0			1.00	0.13
San Pablo, Contra Costa Junior College:									
Up	1040	0.073	118	15.0	11.0	0.16	1		First shock.
North	1041	0.071	118	14.8	10.0	0.18	5		
East	1042	0.072	114	14.4	10.0	0.10	2		
North	46	3.51	1		11.0			1.26	0.05
West	47	3.40	1		11.0			2.25	0.03

TABLE 5.—Composite of strong-motion instrument data for 1969—Continued

Station and component	Instrument No.	T ₀	V	Sensitivity	e	Maximum				Remarks	
						Acceleration		Displacement			
						Period	Amplitude	Period	Amplitude		
NORTHERN CALIFORNIA EARTHQUAKES OF OCTOBER 1—Continued											
San Pablo, Contra Costa Junior College:											
Up	1040	0.073	118	15.0	11.0	0.22	3			Second shock.	
North	1041	0.071	118	14.8	10.0	0.21	3				
East	1042	0.072	114	14.4	10.0	0.28	3				
North	46	3.51	1		11.0			1.27	0.04		
West	47	3.40	1		10.0			1.12	0.04		
SOUTHERN CALIFORNIA EARTHQUAKE OF OCTOBER 24											
Los Angeles, 1640 Marengo, 1st floor:											
Down	419	0.048	126	7.6	10.0					Not measurable.	
S52°W	420	0.051	119	7.6	11.0	0.22	3				
						0.26	3				
						0.27	3			Not measurable.	
S38°E	434	0.053	111	7.6	12.0	0.28	3				
						0.34	3				
Los Angeles, 1640 Marengo, 4th floor:											
Down	427	0.051	119	7.6	11.0					Not measurable.	
N38°W	440	0.055	101	7.6	11.0	0.49	9				
						0.50	10				
						0.54	6			Not measurable.	
S52°W	448	0.051	119	7.6	10.0	0.45	7				
						0.47	8				
						0.43	6			Not measurable.	
Los Angeles, 1640 Marengo, 8th floor:											
Down	449	0.054	106	7.6	10.0						
N38°W	471	0.052	112	7.6	10.0	0.55	18			Not measurable.	
						0.54	12				
						0.51	13				
						0.54	12			Not measurable.	
S52°W	447	0.052	112	7.6	12.0	0.53	10				
						0.51	12				

CENTRAL CALIFORNIA EARTHQUAKE OF OCTOBER 27

Hollister, City Hall:	238	0.067	124	13.8	9.5	0.21	32	---	---
Up						0.19	20	---	---
South	239	0.065	124	12.9	12.9	0.12	22	---	---
						0.10	20	---	---
						0.18	18	---	---
West	240	0.065	122	12.7	8.5	0.26	15	---	---
						0.20	21	---	---
						0.21	20	---	---
						0.25	19	---	---
North	6	2.10	1	---	10.0	---	---	1.60	0.38
						---	---	0.47	0.15
						---	---	0.76	0.12
West	5	2.22	1	---	11.5	---	---	0.31	0.10
						---	---	0.43	0.10
						---	---	0.64	0.09
Hollister, Sago Central:									
Up	V	0.030	---	2.42**	10.0	0.13	21	---	---
						0.11	12	---	---
						0.10	9	---	---
S45°E	B	0.030	---	1.59**	10.0	0.10	34	---	---
						0.08	15	---	---
						0.09	15	---	---
S45°W	A	0.030	---	1.60**	10.0	0.15	39	---	---
						0.13	26	---	---
						0.18	21	---	---

CENTRAL CALIFORNIA EARTHQUAKE OF NOVEMBER 15

Hollister, City Hall:	238	0.068	123	14.2	10.0	---	---	---	Not measurable.
Up						---	---	---	Not measurable.
S01°W	239	0.066	123	13.5	9.0	---	---	---	---
						---	---	---	---
N89°W	240	0.066	122	13.3	10.0	1.18	3	---	---
						1.01	3	---	---
						---	---	---	---
N01°E	6	2.10	1	---	11.0	---	---	1.21	0.08
						---	---	1.31	0.07
						---	---	1.25	0.05

TABLE 5.—Composite of strong-motion instrument data for 1969—Continued

Station and component	Instrument No.	T ₀	V	Sensi- tivity	e	Maximum				Remarks
						Acceleration		Displacement		
						Period	Ampli- tude	Period	Ampli- tude	
CENTRAL CALIFORNIA EARTHQUAKE OF NOVEMBER 15—Continued										
N89°W	5	2.20	1	-----	11.0	-----	-----	2.19	0.07	
						-----	-----	1.56	0.07	
						-----	-----	2.31	0.05	
CENTRAL CALIFORNIA EARTHQUAKE OF NOVEMBER 17										
Cholame Shandon, Station No. 2:										Not measurable.
Down	254	0.057	98	7.9	8.0	-----	-----	-----	-----	
N51°E	210	0.067	76	8.4	10.0	0.24	3	-----	-----	
N39°W	228	0.056	100	7.7	8.0	0.28	3	-----	-----	
San Luis Obispo:										
Up	295	0.081	114	18.6	11.5	0.26	3	-----	-----	
						0.25	4	-----	-----	
S54°W	296	0.079	120	18.8	10.5	0.20	3	-----	-----	
						0.28	7	-----	-----	
						0.21	7	-----	-----	
N36°W	297	0.081	116	18.6	10.6	0.41	8	-----	-----	
						0.19	8	-----	-----	
						0.21	5	-----	-----	
						0.15	4	-----	-----	
CENTRAL CALIFORNIA EARTHQUAKE OF DECEMBER 10										
Cholame Shandon, Station No. 2:										Not measurable.
Down	254	0.057	102	7.9	8.0	-----	-----	-----	-----	
N51°E	210	0.067	77	8.4	10.0	0.20	4	-----	-----	
N39°W	211	0.063	78	7.6	10.0	0.15	3	-----	-----	

* Asterisk following number in sensitivity column indicates RFT-250 (film record) which has sensitivity of 7.6 centimeters at a 4 magnification.

** Two asterisks following number in sensitivity column indicate sensitivity of MO-2 film record.